ALGEBRA MADE EASY

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ALGEBRA MADE EASY

(MATRICULATION ALGEBRA)

FOR

MATRICULATION STUDENTS OF THE INDIAN UNIVERSITIES

BY

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FORTIETH EDITION

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PREFACE

THE present work is intended as a text-book in Algebra for all classes of students in our schools It differs, however, in several respects from the existing text-books on the subject at present in use

Algebra like every other branch of Mathematics should be studied more as a subject for mental discipline than for anything else An intelligent grasp of principles therefore is to be chiefly aimed at and not the mere learning by rote of a certain number of rules with some readiness in their application. This is the ideal I have ever kept in view in the preparation of this work

The elementary principles of the subject have been dwelt upon at considerable length in the earlier chapters of the book The full import of negative quantities has been explained it is believed, with some degree of clearness, almost at the very outset, and rules for their addition and subtraction have subsequently been deduced therefrom by a very simple mode of reasoning

The proposition of each article after being clearly demonstrated has been copiously illustrated by a number of select examples, a much larger number of other examples, arranged progressively, has then been added as an exercise for the student The last article of each chapter consists of a number of miscellaneous examples fully worked out as interesting illustrations of special artifices, these again are followed by similar others for exercise.

The chapters on Formulæ and Factors will, it is hoped, be particularly acceptable to the young learner The subject of factorisation has been treated exhaustively as far as the limits of this work would allow The last chapter, on Elimination and Miscellaneous Artifices, will I hope, be of considerable use to the more advanced student.

Entrance Examination Papers of the Calcutta University from 1858 to 1890 will be found at the very end The more important and difficult problems from these papers are fully worked out in the body of the work in illustration of the principles upon which their solutions depend, whilst others, comparatively simpler, have been suitably introduced among the exercises just to give the student an opportunity of reassuring himself, when successful in working them out with unaided exertion, that his knowledge has to some extent at least, come up to the University standard With the examination papers are also given references to the pages where these problems are to be found in the body of the work.

Instead of ending the book with a collection of miscellaneous examples promiscuously arranged, I have added a number of miscellaneous examples in the form of separate examination papers, any one of which may be regarded as a good exercise for the student at a setting of about two hours and a half.

The entire book contains nearly 3000 examples in all, of which over 400 are fully worked out Many of these examples have been specially devised for this work whilst for the rest I am indebted to several of the standard works of English authors as also to many of the examination papers of the Indian and English Universities

I have attempted to make the work useful to the school student as a means of acquiring algebraical skill along with a sound knowledge of principles, and I have spared no pains for it It is now for all experienced teachers of mathematics to judge as to how far I have been successful in my endeavour. To gentlemen interested in the cause of education I shall be much obliged if they will kindly communicate to me any corrections or suggestions that they may consider necessary for the improvement of the work.

DACCA · *March, 1890.* K. P. BASU

PREFACE TO THE SECOND EDITION

A FEW words of explanation seem to be necessary in connection with the publication of this edition The first edition having been published rather unseasonably last year, I did not at all anticipate that a second edition would be in demand so soon Accordingly the work of re-publication was not taken at hand earlier than January last. But the book beginning to be received with increased favour in different educational circles with the commencement of the new academic session, the first edition, consisting of 2250 copies, was found to be exhausted before the end of the last month Hence, in the interests of the students of all those schools in which the book has been adopted as a text-book, my publisher had no other alternative than to hasten the work by all possible means In consequence of this, I am sorry, I have not been able to give the book as thorough a revision as I intended, nor to effect such improvements as have been kindly suggested by some friends.

DACCA: *March 1891* K. P. BASU

PREFACE TO THE FIFTH EDITION

IN this edition the bulk of the work has increased by about 60 pages The additions that have been made are as follows · (1) an increase in the number of examples of exercises in the earlier chapters of the book; (2) the insertion of examples with *Fractional Indices* in the chapters on *Multiplication* and *Division*, (3) the introduction of three sets of Miscellaneous Exercises in suitable places in the body of the work, (4) an article on the Method of finding the *Cube Root* of a Compound Algebraical Expression, and (5) a chapter on *Quadratic Equations* For several of these improvements I am indebted to the kind and repeated suggestions of friends who are practical workers in the field of education It is therefore hoped that the present edition will be found considerably more useful than its predecessors

DACCA *January, 1894.* K P BASU

PREFACE TO THE SIXTH EDITION

IN this edition the book has been thoroughly revised and answers to the examples in all the exercises have been carefully verified. Some additions and alterations have been occasionally made, but they do not deserve any special mention I am indebted to several friends for their kindness in pointing out errors and misprints My special thanks are due to Babu Bepinbihari Ganguly, B A, Teacher, Jubilee School, Dacca, and to Moulvie Abdullah Khan, Teacher, D B School, Dipalpur (Montgomery)

DACCA *April 1895* K P BASU

PREFACE TO THE THIRTY-SEVENTH EDITION

IN this edition which has been revised by me, certain new matters have been added in accordance with the recent Syllabuses of Studies prescribed by the Education Department of the Bengal Government The order of the subject-matters has also been altered to some extent so as to make the book more useful and interesting to the student in general.

The subject of Graphs has been treated more fully owing to its growing importance and has been introduced in an earlier portion of the book to familiarise the student with the principles of the Graphic method from the beginning.

No pains have been spared to make the book most exhaustive by necessary additions and alterations, and Prof K P Basu's characteristic mode of treatment which has led to the great excellence and success of the present treatise as a text book has been followed in all such changes

It is therefore hoped that in its present form the book will be found to be more useful to the teacher as well as to the pupil

My best thanks are due to my esteemed friend Prof Monoranjan Das-Gupta, M A of the City College, Calcutta, and Babu Tridibesh Basu, youngest son of Prof K P Basu, for their invaluable assistances in the preparation of the present edition

CALCUTTA, *April, 1930* N N SEN

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ALGEBRA MADE EASY

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INTRODUCTION

1. How things are measured and represented by number. This will be best explained by taking up some particular instances familiar to the student

(i) If we want to know the length of a piece of cloth we are satisfied when we find how often this length contains a smaller length called a *cubit* (the distance between the elbow and the tip of the middle finger)

(ii) If we want to know the distance between Dacca and Calcutta we are satisfied when we are told how often this distance contains a smaller distance called a *mile*

(iii) If we want to know the value of a sum of money we are satisfied when we are told how often this sum contains a smaller sum called a *rupee*

(iv) If we want to know the weight of a quantity of rice we are satisfied when we find how often this weight contains a smaller weight called a *seer*

From the above instances it is clear that whenever we have to measure a thing we do so by finding how often it contains a smaller thing of the same kind The 'smaller thing" chosen for this purpose is called the **unit** and the *number* which shows how often this unit is contained in the thing measured is called the *numerical measure* (or simply, the **measure**) of the latter thus in the first instance, the *unit of length* is a *cubit*, in the second, the *unit of distance* is a *mile*, in the third, the *unit of money* is a *rupee*, and in the fourth instance, the *unit of weight* is a *seer* Again, if we know that the piece of cloth is 10 cubits long that the distance between Dacca and Calcutta is 260 miles, that the sum of money is 500 rupees and that the weight of the rice is 25 seers, then, 10 is the *measure* of the length of the cloth, 260 is the *measure* of the distance between Dacca and Calcutta,

500 is the *measure* of the sum of money, and 25 is the *measure* of the weight of the rice

A thing is said to be *represented* by the number which shows how often that thing contains the unit of its kind thus in the above instances the length of the piece of cloth is represented by 10, the distance between the two places is represented by 260, and so on

Note 1 *Such expressions as "a sum of money estimated in pounds =30," "a distance estimated in miles=25', and the like, respectively mean "the numerical measure of a sum of money when a £ is the unit, is 30," "the numerical measure of a distance when the unit is a mile, is 25," &c*

Note 2 *It must be clearly understood that one and the same thing will be represented by different numbers when the units are different thus taking a foot as the unit, a length of 10 feet is represented by 10, but if the unit be 2 feet, the same length is represented by 5*

Example 1 If the *unit of length* be a foot, what will be the measure of 5 yards and 2 feet?

5 yards and 2 feet, being equivalent to 17 feet, evidently contains the unit of length (*i e*, a foot) 17 times

Hence, the required *measure* is 17

Example 2 If a minute and a half be represented by 30, what is the *unit of time*?

A minute and a half is equivalent to 90 seconds

Now since 30 is the *measure* of 90 seconds, it is clear that the *unit of time* is contained 30 times in 90 seconds

Hence, the *unit of time* is $\frac{1}{30}$th part of 90 seconds, and is therefore equal to 3 seconds

EXERCISE 1.

1. What will be the *measure* of 2 *maunds* and 20 *seers*, when a *seer* is the *unit of weight*?

2. What will be the measure of the same weight, when 10 *seers* is the *unit*?

3. If a distance of 360 miles be represented by 30, what is the *unit of distance*?

4. If the same distance be represented by 45 what is the *unit* ?

5. If a sum of 400 rupees be represented by 16 what will be the *measure* of Rs 225 ?

6. If a length of 7 feet 4 inches be represented by 22, what will be the *measure* of 4 feet ?

7. What must be the *unit of time* in order that 3 hours and 45 minutes may be represented by 5 ?

8. If the *unit of time* be 15 seconds what time will be represented by 60 ?

9. If the *unit of weight* be $7\frac{1}{2}$ lbs, what number will represent $2\frac{1}{7}$ cwt ?

10. If 8 square feet be the *unit of area*, what number will represent an area of 18 square inches and what will represent 18 square yards ?

11. If an area of 125 sq ft be represented by $8\frac{1}{3}$ how many square yards are there in 3 times the unit area ?

12. What is the unit of money if a sum of £10 2*s* 6*d* be represented by 27 ?

13. If 7*s* 8*d* be the unit of money, what will be the measure of £7 13*s* 4*d* ?

14. If Rs 5 11*a* 2*p* be the unit of money, what will be the measure of Rs 51 4*a* 6*p* ?

15. If 23 seers 5 chattacks be the unit of weight what will be the measure of 16 maunds $12\frac{3}{4}$ seers ?

16. If Rs 20 10*a* be represented by $5\frac{1}{2}$, what will be the measure of Rs 45, supposing the new unit to be 3 times the former ?

17. If 273 be the measure of 9 cwt 3 qrs, what number will represent one ton, supposing the new unit to be one-eighth of the former ?

18. If 84 be the measure of 39 yds 2 ft, what number will represent 75 yards, supposing the new unit to be three-seventeenths of the former ?

19. If 26 days 10 hours and 26 minutes be represented by 120, what number will represent a leap year, supposing the new unit to be 47 minutes 13 seconds less than the former ?

20. In the preceding example what would be the answer if the latter unit exceeded the former by 6 hours 54 minutes 47 seconds ?

2. Different uses of the word Quantity.

(i) Any thing that can be represented by *number* is called a *quantity* Thus time, weight, money, distance, &c, which all admit of numerical representation, as shown in the preceding article, are quantities

(ii) *Quantity* is also often used in the sense of *number*, integral or fractional

(iii) An algebraical *expression* also is sometimes called a *quantity* [We shall refer to this again in its proper place]

N B Quantities like weight, money, distance, area, &c, are often spoken of as ***concrete quantities****, as distinguished from* ***numerical quantities*** *which mean only Arithmetical* ***numbers****, integral or fractional*

[**Note** *Any whole number is called an* ***integer*** *or an* ***integral*** *number*]

3. What is Algebra ? Algebra like Arithmetic, is a science of *numbers* with this distinction that the numbers in Algebra are *generally* denoted by *letters* instead of by *figures*

Hence, whenever concrete quantities come under the domain of Algebra, it is *only* their numerical *measures* (*i e* the abstract numbers which represent them) with which we must concern ourselves

Note *The name 'Algebra' is derived from the title of a certain Arabian treatise* ***'Al-jebr w'al Muqabalah'*** *This book was translated by early European scholars who first learnt of Algebra from the Arabs But as in Arithmetic, so in Algebra, the Arabs got their first lessons from the ancient Hindus whose contributions to this science are of a fundamental character Even some of the technical terms which are commonly used in modern Algebra are of Hindu origin*

CHAPTER I

SYMBOLS : SIGNS : SUBSTITUTIONS

4. Symbols. The *letters* of the alphabet a b, c &c are used to denote numbers and the signs $+$, $-$, $\times$, $\div$ $=$, $\therefore$ &c are used either to denote operations to be performed upon the numbers to which they are attached or as abbreviations These *letters* and *signs* are called *symbols*

The letters as distinguished from the signs are called *symbols of quantity*

5. The Plus Sign. The sign $+$ is read *plus* and when placed before a number indicates that the number is to be *added* to what precedes it Thus $a+b$ (which is read a *plus* b) means that the number denoted by b is to be *added* to that denoted by a, hence, if a denotes 5 and b denotes 3, $a+b$ denotes 8 Again, $a+b+c$ means that the number denoted by b is to be added to that denoted by a and to the result thus obtained is to be added the number denoted by c, hence, if a, b c denote 5, 3, 2 respectively $a+b+c$ denotes 10

6. The Minus Sign. The sign $-$ is read *minus* and when placed before a number indicates that the number is to be *subtracted* from what precedes it Thus $a-b$ (which is read a *minus* b) means that the number denoted by b is to be *subtracted* from that denoted by a, hence, if a denotes 8 and b denotes 3, $a-b$ denotes 5 Again, $a-b-c$ means that the number denoted by b is to be subtracted from that denoted by a, and from the result thus obtained, the number denoted by c is to be subtracted, hence, if a, b, c denote 8, 3 1 respectively, $a-b-c$ denotes 4

N B When any number of quantities are connected with one another by the signs ***plus*** *and* ***minus*** *the order of the operations is from* ***left to right*** *Thus $a-b+c$ means that the number denoted by b is to be subtracted from that denoted by a and to the result thus obtained, is to be added the number denoted by c*

7. The Sign Plus or Minus. The sign $\pm$ is read *plus* or *minus* and when placed before a number indicates that the number is to be *either added to* or *subtracted from*

what precedes it Thus if a denote 7 and b denote 2, $a \pm b$ (which is read *a plus* or *minus b*) denotes *either* 9 *or* 5

8. The Sign of Difference. The sign $\sim$ when placed between two numbers indicates that the less of the two is to be subtracted from the greater Thus if a denote 5 and b denote 8, $a \sim b$ denotes 3

9. The Sign of Multiplication. The sign $\times$ is read *into* and when placed between two numbers indicates that the number on the right of it is to be *multiplied* by that on the left

Thus $a \times b$ (which is read *a into b*) means that the number denoted by b is to be multiplied by that denoted by a, hence, if a denote 5 and b denote 3 $a \times b$ denotes 5 *times* 3 or 15

The sign of multiplication is generally omitted when its position is between two numbers either (1) *both* of which are denoted by letters or (2) the *first* of which is denoted by a *figure* and the second by a letter Thus ab is used for $a \times b$, and $4a$ for $4 \times a$

Note The reason why 83 cannot be used for 8×3 is clear, because in Arithmetic 83 has already been understood to mean 80+3

Sometimes the sign $\times$ is replaced by a dot thus $a \cdot b$ and $5 \cdot 4$ respectively mean the same as $a \times b$ and 5×4 The dot so used is always placed as shown in the above instances in order to distinguish it from the decimal point which is put a little higher up, thus $5 \cdot 4$ is read *five into four* whereas 5.4 is read *five decimal four*

10. The Sign of Division. The sign $\div$ is read *by* and when placed between two numbers indicates that the number on the left of it is to be *divided* by that on the right Thus $a \div b$ (which is read *a by b*) means that the number denoted by a is to be divided by that denoted by b, hence, if a denote 6 and b denote 3, $a \div b$ denotes 2 Similarly $a \div b \div c$ means that the number denoted by a is to be divided by that denoted by b, and the result thus obtained, is to be divided by the number denoted by c

N B When any number of quantities are connected together by the signs of multiplication and division, the order of the operations is always from ***left to right.*** *Thus $a \times b \div c$ means that the number*

denoted by b is to be multiplied by that denoted by a, and the result thus obtained, is to be divided by the number denoted by c Similarly, $a-b\times c$ means that the number denoted by a is to be divided by that denoted by b and the result thus obtained, is to be multiplied by the number denoted by c

Note *a divided by b is also often expressed as $\frac{a}{b}$ thus $\frac{a}{b}$ means the same as $a-b$*

11. Expression; Term. Any intelligible collection of letters figures and *signs of operation* is called an *Algebraical Expression* Such a collection is also sometimes called an *Algebraical Quantity* or briefly, a *Quantity* [See Art 2]

Note *Signs like +, −, ×, −, which indicate the operations to be performed upon the numbers to which they are attached, are called* ***signs of operation***

The parts of an Algebraical Expression that are connected by the sign + or − are called its *terms*

Thus $5a+ab-c\times d-8c\times f-g$ is an algebraical expression of which the terms are $5a$ $ab-c\times d$ $8c\times f-g$

Expressions are either **simple** or **compound.** A *simple* expression is one which has no parts connected by the sign + or −, *i e*, which consists of only one term, as $3ab$ and is also called a *Monomial* A *compound* expression consists of two or more terms, if it consist of two terms, as $2a+5bcd$ it is called a *Binomial*, if of three terms, as $a+bc+8efg$, a *Trinomial*, and if of more than three terms a *Multinomial* or a *polynomial*

12. Functions; Variables. Any expression involving a letter is called a *function* of that letter Thus x^3+5x+8 is a function of x, a^2+ab+b^2 is a function of a and b, $a^3+b^3+c^3+2abc$ is a function of a b and c, and so on

The letters of which a function consists are called its *variables* Thus $x^2+5xy+y^2$ is a function of which the variables are x and y

13. Sign of Equality. The sign = is read 'equals' or "is equal to" and when placed between two *expressions* indicates that they are equal to one another Thus $b+c=a$ (which is read *b plus c equals a*) means that the number denoted by $b+c$ is equal to that denoted by a

EXAMPLES

N B (1) A distinction must be observed between $a \div b \times c$ *and* $a \div bc$ *The latter means that the number denoted by* a *is to be divided by that denoted by* bc*, whereas the former means that the number denoted by* a *is to be divided by that denoted by* b*, and the result thus obtained, is to be multiplied by the number denoted by* c *That is to say, when the sign of multiplication is omitted between any number of quantities the result obtained by multiplying them together is to be regarded as* ***simple quantity.***

N B (2) In finding the value of any ***expression*** *the values of the several* ***terms*** *which it contains must be first determined by the process mentioned in the Note of Art 10 and* ***afterwards*** *the value of the whole expression is to be found by the process mentioned in the Note of Art 2 Thus in finding the value of the expression* $a \times b - c \div d \times e + f \times g$ *we must first of all find the values of the three terms, namely,* $a \times b$*,* $c \div d \times e$ *and* $f \times g$ *, then subtract the value of the second term from that of the first, and to the result thus obtained, add, the value of the third*

The above principles will be sufficiently illustrated by the following examples

Example 1 If $a=2$ $b=3$, $c=5$, find the value of $5a+8b+7c$

$$5a = 5\times a = 5\times 2 = 10,$$
$$8b = 8\times b = 8\times 3 = 24,$$
$$7c = 7\times c = 7\times 5 = 35$$

Therefore $5a+8b+7c=10+24+35$
$=34+35=69$

Example 2 If $a=8$, $b=5$, $c=2$, find the value of $6a-5b+4c$

$$6a = 6\times a = 6\times 8 = 48,$$
$$5b = 5\times b = 5\times 5 = 25,$$
$$4c = 4\times c = 4\times 2 = 8$$

Therefore, $6a-5b+4c=48-25+8$
$=23+8=31$

Example 3. If $m=3$ $n=7$, $t=9$, $v=4$, find the value of $7m \div 2n \times 8t \div 3v$

As the order of the operations is from *left to right*, we must proceed as follows Divide $7m$ by $2n$, multiply $8t$ by the result, and then divide the result thus obtained by $3v$

Now (1) $7m-2n=\frac{7m}{2n}=\frac{7\times3}{2\times7}=\frac{3}{2}$;

(2) $\frac{3}{2}\times8t=\frac{3}{2}\times8\times9=3\times4\times9$.

(3) $3\times4\times9-3v=\frac{3\times4\times9}{3\times1}=9$

Hence the required value $=9$

Example 4. If $a=1$, $b=2$, $c=3$, $d=6$, $e=5$, $f=0$, find the value of $abc-d-b\times a+def+b-a\times c-d-bc$

The given expression consists of 5 terms, namely abc, $d-b\times a$ def $b-a\times c$ and $d-bc$

Now (1) $abc=a\times b\times c=1\times2\times3=6$,
(2) $d-b\times a=6-2\times1=3\times1=3$,
(3) $def=d\times e\times f=6\times5\times0=0$,
(4) $b-a\times c=2-1\times3=2\times3=6$,
(5) $d-bc=\frac{d}{bc}=\frac{6}{2\times3}=1$

Hence, the required value $=6-3+0+6-1$
$=3+6-1=8$

EXERCISE 2.

If $a=8$ $b=2$ $c=4$ find the numerical values of the following expressions

1. $b+c\times a$ **2.** $a-b\times c$ **3.** $a-c\times b$
4. $a-cb$ **5.** $a-3\times b$ **6.** $a-3b$
7. $a-c-b$ **8.** $b+a-c$ **9.** $3a-4c+2b$
10. $a-c-b+a-c$ **11.** $a-c-2\times b$ **12.** $a-c-2b$
13. $5a-2c$ **14.** $5a-2\times c$
15. $4bc-a-4\times b+c-2b$
16. $80-c\times ab+80-ca\times b$
17. $3ca-16b+5a-16\times b-a-2c\times c-b\times4$
18. $48a-c-b\times6-4c-3a-2c-4\times3-b\times8$
$+6b-a-2\times c-3\times5$

If $m=2$, $n=3$ $p=4$ $q=0$, $r=7$ $s=10$, find the numerical values of the following expressions

19. $8m-3p-mn+q\times 3r+5s-2\times p$

20. $s\times 6-5m\times 8p-16n$.

21. $mn+5qs-3s-m-5n+4r-3p\times 6m$

22. $3\times r-5\times s-7\times p-8rs-m-3\times n-7p+5m-2r\times 7$

23. $4\times\frac{n-m}{p}-3\times\frac{p-m}{n}+2\times\frac{p-n}{m}$

24. $\frac{11r+n}{p+q}\times 2pm+\frac{14s+4n+2p}{sn+2}$.

25. $\frac{3m+2n}{q+p}-\frac{4p-3n}{q+r}+\frac{2p+3m}{q+m}$

14. Factor. If any number be equal to the product of two or more numbers, each of the latter is called a *factor* of the former

[Note *The product of two or more numbers is the result obtained by multiplying them together*]

Thus, 3, 5 and 7 are the factors of 105 $105=3\times 5\times 7$

Similarly 3, a, b and x are the factors of $3abx$, because $3abx=3\times a\times b\times x$

15. Co-efficient. The number expressed in figures or symbols which stands before an algebraical quantity as a multiplier, is called its *co-efficient* Thus in $5abc$, 5 is the co-efficient of abc $5a$ is the co-efficient of bc and $5ab$ is the co-efficient of c

A co-efficient which is purely a numerical quantity is called a **numerical co-efficient;** thus, in $5abc$, the co-efficient of abc is numerical

A co-efficient which is not wholly numerical is called a **literal co-efficient;** thus, in $5abc$ co-efficients of bc and c are *literal*

[Note *When no arithmetical number stands before a quantity the number 1 is understood, thus a is understood to mean 1a*]

16. Power; Index; Exponent. If a quantity be multiplied by itself any number of times, the product is called a *power* of that quantity Thus, $a\times a$, $a\times a\times a$ $a\times a\times a\times a$, &c, are powers of a

$a\times a$ is called the *second power* or *square* of a and is written a^2,

$a\times a\times a$ is called the *third power* or *cube* of a and is written a^3,

$a\times a\times a\times a$ is called the *fourth power* of a and is written a^4

$a\times a\times a\times a\times a\times$&c to n factors is called the *nth power* of a and is written a^n

The small figure or letter placed above a quantity and to the right of it to express its power is called the **Index** or **Exponent** of that power Thus, 2, 3, 5 m are respectively the *indices* or *exponents* of a^2, a^3 a^5, a^m

[*Note* a^2 *is usually read* ***"a squared"***; a^3 *is read* ***"a cubed"***, a^4 *is read* ***"a to the fourth"*** *or simply,* ***"a fourth"***; *and so on Thus* a^n *is read* ***"a to the nth"*** *or* ***"a nth"***.

The quantity a itself is called the ***first*** *power of a and thus a is understood to mean* a^1]

17. Dimensions and Degree of a Product. Each of the letters which occur as factors of an algebraical product is called a *dimension* of the product, and the number of the letters is called the *degree* of the product Thus a^2x^5y which is equivalent to $a\times a\times x\times x\times x\times x\times x\times y$, is said to be of *eight dimensions*, or of the *eighth degree*, similarly $ab^2c^4d^5$ is said to be of *twelve dimensions* or of the *twelfth degree*

A numerical co-efficient is not counted Thus $5ab^2c^3$ and ab^2c^3 are both said to be of *six dimensions* or of the *sixth degree*

When an algebraical expression contains terms of different dimensions the degree of the term which is of the highest dimensions is also called the *degree of the expression*

18. Homogeneous Expression. An algebraical expression is said to be *homogeneous* when all its terms are of the same dimensions Thus the expression $5a^3b-7a^2bc+8b^2c^2$ is homogeneous, for each of its terms is of four dimensions

EXAMPLES

Example 1. If $a=3$, find the numerical value of a^5-5a

We have $a^5=a\times a\times a\times a\times a$

$=3\times3\times3\times3\times3=243$,

and $5a=5\times a$

$=5\times3=15$

Hence, the given expression $=243-15=228$.

Example 2. If $a=4$, find the numerical value of $2a^5-5a^2$

We have $2a^5=2\times a\times a\times a\times a\times a$

$=2\times 4\times 4\times 4\times 4\times 4$

$=2048$,

and $5a^2=5\times a\times a$

$=5\times 4\times 4=80$

Hence the given expression $=2048-80=1968$

Example 3. If $a=2$, $b=3$, $c=4$, $d=5$, find the numerical value of $\dfrac{a^5b^3d}{c^2}$.

$$\text{The given expression}=\frac{a\times a\times a\times a\times a\times b\times b\times b\times d}{c\times c}$$

$$=\frac{2\times 2\times 2\times 2\times 2\times 3\times 3\times 3\times 5}{5\times 4}$$

$$=2\times 3\times 3\times 3\times 5=270$$

EXERCISE 3.

If $a=8$, $b=12$, $c=4$, $m=7$, $n=6$, $x=2$, $y=3$, find the values of

1. $3x^3$ **2.** $7a^2-b$ **3.** $2x^7-7n^2$

4. $8cy^3-axy^2$ **5.** $5c^3-3a^3$ **6.** $7bx^3y^2-mn^4$

7. a^x-c^y **8.** $9a^3b^2c^4-8n^2x^8y^2-b^2y-x$

9. $2x^yb-a^2b^x$ **10.** $3c^nx^b-a^my^3$

11. Find the value of $y^6-65y^4+66y^2-21y+40$, when $y=8$

12. Find the value of $8x^4+6x^3+11x^2+13x+29$ when $x=\cdot 75$

13. Find the value of $15a^3-34a^4+7a-4a^2+35a^5-3$, when $a=\frac{4}{7}$

14. Find the value of $23+20m+78m^5-199m^6+25m^8$, when $m=2\cdot 6$

15. Find the value of $30y^7-51y^4+35y-563y^5-19$, when $y=3\cdot 1$

16. Find the value of $64n^{10}-55n^4+32n^6-121n^8+64n^2-1n^5+79$ when $n=1\cdot 375$

Find the values of $a^3+b^3+c^3-3abc$

17. When $a=29$, $b=24$, $c=27$

18. When $a=5{\cdot}625$, $b=3{\cdot}625$, $c=4{\cdot}625$

19. When $a=44\frac{3}{7}$ $b=51\frac{1}{7}$, $c=58\frac{3}{7}$

20. When $a=1667$, $b=1674$ $c=1659$

19. Roots. That quantity whose square (or second power) is equal to any given quantity a, is called the *square root* of a, and is denoted by the symbol $\sqrt[2]{a}$, or more simply, by $\sqrt{a}$, thus $3=\sqrt{9}$, because $3^2=9$

That quantity whose cube (or third power) is equal to any given quantity a, is called the *cube root* of a and is denoted by the symbol $\sqrt[3]{a}$, thus $2=\sqrt[3]{8}$, because $2^3=8$

Generally, that quantity, whose n^{th} power, where n is any whole number is equal to any given quantity a, is called the n^{th} *root* of a, and is denoted by the symbol $\sqrt[n]{a}$ Thus $2=\sqrt[5]{32}$ because $2^5=32$, $3=\sqrt[4]{81}$, because $3^4=81$ and so on

The sign $\sqrt{}$ is often called the *Radical sign* It is said to be a corruption of the letter *r*, the first letter of the word *radix*

Note *$\sqrt{a}$, which means the square root of a, is often read simply as "root a"*

20. Brackets. Each of the symbols ( ), { }, and [ ], is called a *pair of brackets* When an algebraical expression is enclosed within brackets it is to be regarded as a *single* quantity by itself Thus $(a+b)x$ means that the number denoted by x is to be multiplied by that denoted by $a+b$, whereas $a+bx$ means that x is to be multiplied by b and the product added to a

Hence, the expression $d+(a+b)x$ must be regarded as a *binomial*, the two terms being d and $(a+b)x$ Similarly, $c-\{d+(a+b)x\}$ also must be regarded as a *binomial*, the terms being c and $\{d+(a+b)x\}$, whereas, if the brackets be taken off, $c-d+a+bx$ is a *multinomial* consisting of four terms, namely, c, d, a and bx

Sometimes instead of enclosing an expression within a pair of brackets a line called a **vinculum** is drawn over it

Thus $a-\overline{b-c}$ and $a-(b-c)$ have the same meaning

N B From the above it is easy to understand the distinction between $\sqrt{\overline{a+b}}$ or $\sqrt{(a+b)}$ and $\sqrt{a}+b$, either of the first two expressions means the square root of the number denoted by $a+b$, whereas the last

means that b is to be added to the square root of a Similarly, $\sqrt{ab}$ *or* $\sqrt{(ab)}$, *means the square root of the number denoted by ab, whereas* $\sqrt{a}b$ *means the product of b and the square root of a*

Note *The three different kinds of brackets* ( ), { }, [ ] *are often called respectively* ***parentheses, braces*** *and* ***crotchets***

EXAMPLES

Example 1 If $a=2$, $b=4$, $c=9$, find the values of

$\sqrt{c}b+\sqrt{b}+5$, $\sqrt{cb}+\sqrt{(b+5)}$ and $\sqrt[3]{2b}+\sqrt{4}a$

(i) $\sqrt{c}b+\sqrt{b}+5 \;=\sqrt{9}\times 4+\sqrt{4}+5$
$=3\times 4+2+5$
$=12+2+5=19$

(ii) $\sqrt{cb}+\sqrt{(b+5)}=\sqrt{9\times 4}+\sqrt{(4+5)}$
$=\sqrt{36}+\sqrt{9}$
$=6+3=9$

(iii) $\sqrt[3]{2b}+\sqrt{4}a \;=\sqrt[3]{2\times 4}+\sqrt{4}\times 2$
$=\sqrt[3]{8}+2\times 2$
$=2+4=6$

Example 2. If $a=3$, $b=5$, $c=8$, $d=12$ $e=20$, find the difference between the numerical values of

$$a\{c+b^2-a(e-d)\} \text{ and } a\{c+\overline{b^2-a}(e-d)\}$$

The 1st expression $=3\times\{8+5^2-3\times(20-12)\}$
$=3\times\{8+25-3\times 8\}$
$=3\times\{8+25-24\}$
$=3\times 9=27$,

and the 2nd expression $=3\times\{8+(5^2-3)\times(20-12)\}$
$=3\times\{8+22\times 8\}$
$=3\times\{8+176\}$
$=3\times 184=552$

Thus the reqd diff $=552-27=525$

Example 3. If $m=10$ $n=8$ $p=2$ $q=12$ $r=15$, find the difference between the numerical values of the expressions

$$[\{rm-2q-n(pq-m)\}-p]\times(r-m-p)$$

$$\text{and } [\{rm-2\overline{q-n}(pq-m)\}-p]\times r-\overline{m-p}$$

The first expression

$=[\{15\times10-2\times12-8\times(2\times12-10)\}-2]\times(15-10-2)$
$=[\{150-24-8\times14\}-2]\times3$
$=[\{126-112\}-2]\times3$
$=[14-2]\times3=7\times3=21$

and the second expression

$=[\{15\times10-2\times(12-8)(2\times12-10)\}-2]\times15-(10-2)$
$=[\{150-2\times4\times14\}-2]\times15-8$
$=[\{150-112\}-2]\times15-8$
$=[38-2]\times15-8$
$=19\times15-8=285-8=277$

Thus the reqd. difference $=277-21=256$

EXERCISE 4.

If $a=7$, $b=3$, $c=8$, $d=9$, $e=4$, $f=0$, $m=5$, $n=2$, $p=1$ find the values of

1. $\sqrt[3]{cen}$ **2.** $\sqrt[5]{ce}$ **3.** $\sqrt[3]{cb}$ **4.** $6\sqrt[6]{b^4d}$
5. $4\sqrt[4]{4e}$ **6.** $4\sqrt[4]{e^4}$ **7.** $2\sqrt{4c^2}$ **8.** $2\sqrt{4}c^2$
9. $m+n\sqrt{d}$ **10.** $\overline{m+n}\sqrt{d}$ **11.** $3\sqrt{p}+c$ **12.** $3\sqrt{c}+p$
13. $\sqrt[3]{3(c+p)}$ **14.** $3\sqrt[3]{8}(b+3c)$ **15.** $3\sqrt[3]{8(b+3c)}$
16. $f\sqrt{m}+d$ **17.** $f\sqrt{a+d}$ **18.** $3d-(2e-n)$
19. $3d-2(e-n)$ **20.** $3(d-2e)-n$ **21.** $(3d-2)e-n$
22. $(3d-2)\overline{e-n}$ **23.** $3\{d-(2e-n)\}$ **24.** $3(d-2)(e-n)$
25. $7c-(b^2-n^2)$ **26.** $(7c-b)^2-n^2$ **27.** $7c-(b^2-n)^2$
28. $7(c-b)^2-n^2$ **29.** $\{7c-(b^2-n)\}^2$
30. $\sqrt[3]{c+3p+4e}(p+b)^3$ **31.** $\sqrt[3]{c}+3p+4e(p+b)^3$
32. $\sqrt[3]{c}+\overline{3p+4e}(p+b)^3$ **33.** $\sqrt[3]{c}+(3p+4e)p+b^3$
34. $\sqrt[3]{c}+3\{(p+4)ep+b^3\}$

If $x=2$, $y=3$, $z=4$, $a=6$, $d=8$, $c=5$, $n=9$, $p=1$ find the values of

35. $a(x+y)^2(a-\overline{c-z})^{\frac{3}{2}}$
36. $4\{n-a(d-\overline{a+p})\}\sim4\{\overline{n-a}(d-a)+p\}$
37. $5\{\overline{c+x^2}+y(n-\overline{d-z})\}\sim5\{(\overline{c+x^2}+y)\overline{n-d}-z\}$

38. $[x+y^2\{ap-z(c-\overline{a-x})\}] \sim [\overline{x+y}^2\{(ap-z)c-a\}-x]$

39. $\dfrac{x^2+y^2+z^2-7p^2}{y(c^2+p^2)+y^2+z^2}$

40. $\sqrt{\left\{\dfrac{c^2+z^2+x^2}{c^2-(z^2+x^2)}-\dfrac{n(n^2-\overline{z^2+c^2})}{n^2+z^2-c^2}\right\}}$

21. Like and Unlike Terms. Terms or simple expressions are said to be *like* when they do not differ at all or differ only in their numerical co-efficients, otherwise they are called *unlike*. Thus $3ax^2y^5$ and $5ax^2y^5$ are *like* terms, whereas $3ax^2y^5$ and $5ax^2y^4$ are *unlike*, similarly, abc, $5axbd$, $7a^2b^2$ and c^2d^3c are all *unlike*.

22. Special meaning of the word Sign; Like and Unlike Signs. The word *sign* is often used to denote exclusively the signs + and −. Thus when we speak of the *sign* of a term we mean the *plus* or *minus* sign which stands before it.

Two signs are called *like* when they are *both* + or *both* −, otherwise they are called *unlike*. Thus in the expression $ax^2+bx-cy+d^2-f$ the signs of the 3rd and 5th terms are *like* as also those of the 1st 2nd and 4th, whereas the signs of the 2nd and 3rd terms as well as those of the 4th and 5th are *unlike*.

23. The Signs >, <, and

The sign > when placed between two quantities indicates that the quantity on the left of it is *greater than* that on the right. Thus $a+b > c+d$ means that $a+b$ is greater than $c+d$.

The sign < when placed between two quantities indicates that the quantity on the left of it is *less than* that on the right. Thus $a+x < b+y$ means that $a+x$ is less than $b+y$.

The sign . is used as an abbreviation for the word *because* or *since*.

The sign is used as an abbreviation for the word *therefore* or *hence*.

CHAPTER II

POSITIVE AND NEGATIVE QUANTITIES

24. Quantities of the same class, but of opposite character. When we speak of a quantity of money, it may be either a *gain* or a *loss*, a receipt or a payment Now it is quite clear that whilst a gain adds to our stock, a loss lessens it, moreover, gain and loss are so related that if we gain as much as we lose the effect on our stock is nothing Hence, a quantity of money which forms a *gain* is said to be *opposite in character* to a quantity which forms a *loss*

When we speak of a distance measured from a point, it may be in either of two opposite directions, either towards the north or towards the south of the point, either towards the east or towards the west of the point, either towards the north-east or towards the south-west of the point, and so on It is also clear that distances measured towards the east are so related to those measured towards the west that if we first walk any distance towards the east and then walk an equal distance towards the west there will be no change in our position with respect to the starting point Hence, a distance measured in any direction is said to be *opposite in character* to that measured in the opposite direction

Thus, in the first illustration in so far as a gain and a loss are both looked upon as portions of money, they are said to be quantities of the same class, but as they affect our stock in directly opposite ways (a gain increasing and a loss diminishing it) they are said to be *of opposite character* In the second illustration, a distance measured towards the south of the point as well as one measured towards the north may both be styled *distance*, and thus far they are said to be quantities *of the same class*, but when we consider the directions in which they are measured they must be regarded as *opposite in character*

25. The Signs Plus and Minus under a new aspect. It has been shown in the introduction how concrete quantities are represented by numbers It now remains to be seen how quantities of the same class but of *opposite* character are distinguished in their numerical representation

When we consider any pair of such quantities, we prefix the sign + before the numerical measures of one, and the

sign − before those of the other It is quite immaterial which of the two quantities we select for representation by numbers preceded by the sign +, but when we have once made our choice we must stick to it throughout any connected series of operations The following example will illustrate the principle

Income and *debt* are evidently quantities of opposite character If then we choose to represent incomes by numbers preceded by the sign +, we must represent debts by numbers preceded by the sign −, and *vice versa*

Hence, if in any problem we choose the sign + for incomes and the sign − for debts +30, +45, +90 will respectively represent incomes of £30 £45 and £90 whereas −30 −45 −90 will represent debts of £30, £45 and £90 respectively a £ being the unit But the contrary choice be made +10 +25 +36 will respectively represent debts of £10, £25 and £36 and −10, −25 −36 will represent incomes of £10, £25 and £36 respectively

Hence generally if *a* represent a portion of any quantity, −*a* will represent an equal portion of the quantity opposite in character to it

Graphical Illustration :

A D O C B

Suppose *AB* is a road If a person starting from any point *O* on it *travels towards B* to any point *C* and then *travels back* to *O* it is evident that his position on the road is just the same at the end of his journey as at the commencement Thus it is clear that distances measured along the road from *left to right* are opposite in character to those measured from *right to left* Accordingly if distances measured from left to right be represented by numbers preceded by the sign +, those measured from right to left must be represented by numbers preceded by the sign −, and *vice versa*

On the otherhand if we choose the sign + for distances measured from *right to left*, a distance of −3 miles from any point *O* will mean a distance of 3 miles measured from *O towards the right*, again, if a mile be the unit of distance, and if *C* and *D* be two points on opposite sides of *O* at distances of 5 miles and 4 miles respectively then the distances *OD*, *OC*, *CD* and *DC* will be respectively represented by +4 −5, +9 and −9

From the above instances it is quite clear that the signs + and −, besides being used as signs of the operations of addition and subtraction are also used as *signs of distinction*

between quantities *of opposite character* The signs when used in this sense are often called *signs of affection*

N B When no sign is prefixed to a number, the sign + is understood, thus a and +a have the same meaning

26. Positive and Negative Quantities. Numbers or symbols preceded by the sign + or no sign are called *positive quantities* Whilst those preceded by the sign − are called *negative quantities* Thus each of the expressions 4, +6 a, $+b$, $+c$ is a *positive quantity*, whilst each of −4, −6, $-a$ $-b$, $-c$ is a *negative quantity*

Hence the signs + and − are often respectively called the *positive* and *negative signs*

Note 1 *In "positive and negative quantities" the word quantity is used in the sense of number There is no difficulty however in understanding a* **negative number,** *when the explanation given in Art 25 is remembered*

Note 2 *The* **absolute value** *of a positive or a negative quantity is its value considered apart from its sign Thus if a stands for 5 and b for 3, $+(ab)$ and $-(ab)$ have the same absolute value, namely, 15*

N B It is important to bear in mind the meanings of such expressions as "a gain of −£20," "a rise of −8 inches," "a distance of −5 miles to the north," &c The expressions respectively mean "a loss of £20," "a fall of 8 inches," "a distance of 5 miles to the south," &c

EXERCISE 5.

1. If £4 be the unit, what is meant by "A's gain = −25"?

2. If a trader's loss of £30 be represented by 30, what will represent a gain of £70?

3. If an income of £60 be represented by 15, what will represent a debt of £100?

4. If a debt of £100 be represented by 25, what will represent an income of £400?

5. If a distance of 75 miles to the north of a point be represented by 15, what will represent a distance of 150 miles to the south of it?

6. If a river level rises 12 inches on any day, falls 9 inches the next day and again rises 5 inches on the third, how would you represent the *rises* on successive days, taking 3 inches as the unit of length?

7. A man gains Rs 30 in one year loses Rs 20 in the second year, loses Rs 40 in the third year and gains Rs 60 in the fourth year, how would you represent his *gains* in the successive years taking Rs 2 as the unit?

8. In the preceding question, how would the man's losses be represented?

CHAPTER III

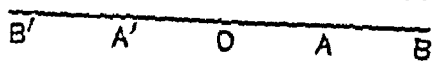
FOUR SIMPLE RULES

I. Addition.

27. Definition. When two or more quantities are united together, the result is called their *sum* and the process of finding the result is called *addition*

Note As *negative numbers are not recognised in Arithmetic, there is clearly a difference between the Arithmetical and the Algebraical significance of the word* ***addition*** *Hence, when we speak of an* ***Algebraic sum,*** *we mean that quantities added together are not necessarily all positive*

28. The result when one positive quantity is added to another. Suppose $B'B$ is a road and that



distances measured from left to right are reckoned positive whilst those measured in the opposite direction, negative

Suppose O, A and B are three points on the road such that OA is 2 miles and AB is 3 miles, then if a mile be the unit of distance and if A and B be situated as shown in the figure OA and AB will be respectively represented by $+2$ and $+3$

If then a man starting from O travels to A in the first hour and from A to B in the second hour, his distance from O at the end of two hours is evidently OB and will therefore be represented by $+5$

Hence since (the distance travelled in the 1st hour)+ (the distance travelled in the 2nd hour) =(the distance travelled *in two hours*), we have $(+2)+(+3)=5$

Hence, generally speaking $(+a)+(+b)=+(a+b)$, or more simply, $(a)+(b)=(a+b)$

Thus, *when two positive quantities are added together, the sum is a positive quantity whose absolute value is equal to the arithmetical sum of the absolute values of those quantities*

29. The result when one negative quantity is added to another. Suppose in the above figure $OA'=2$ miles and $A'B'=3$ miles and that A' is on the left of O and B' on the left of A' as shown in the figure Then the distances OA' and $A'B'$ are respectively represented by -2 and -3

If a man starting from O travels to A' in the first hour and from A' to B' in the second hour, his distance from O at the end of the second hour, will evidently be OB' and will therefore be represented by -5

Hence, since (the distance travelled in the first hour) $+$(the distance travelled in the 2nd hour)$=$(the distance travelled *in two hours*) we have $(-2)+(-3)=-5$

Hence generally speaking, $(-a)+(-b)=-(a+b)$

Thus *when two negative quantities are added together, the sum is a negative quantity whose absolute value is equal to the arithmetical sum of the absolute values of those quantities*

Example 1. Find the sum of $-a$, $-bc$. $-a^2b$, when $a=2$, $b=3$, $c=5$

We have $a=2$, $bc=3\times5=15$, $a^2b=2^2\times3=12$

Hence $(-a)+(-bc)+(-a^2b)=(-2)+(-15)+(-12)$

$$=-(2+15+12)=-29$$

Example 2 Find the value of $(-3c)+(-a^3d)+(b+f+g)$, when $a=3$, $b=-2$, $c=4$, $d=5$, $f=-6$, $g=-8$

We have $b+f+g=(-2)+(-6)+(-8)$

$$=-(2+6+8)=-16,$$

also, $3c=12$,

and $a^3d=3^3\times5=27\times5=135$

Hence the given expression

$$=(-12)+(-135)+(-16)$$

$$=-(12+135+16)=-163$$

EXERCISE 6.

1. Find the sum of -2, -9 and -11

2. Find the sum of $-5x$, $-y$ and $-z$, when $x=2$, $y=3$, $z=5$

3. Find the sum of -7, x and y, and find the result of adding it to -10, when $x=-5$ and $y=-19$

4. Find the value of $2a-3(b+c)$, when $a=-5$, $b=2$, $c=1$

5. Find the value of $(-a^2c^4)+(-a^4b^2)+\{-(c^2-a^2)\}$, when $a=2$, $b=3$, $c=4$

6. Find the sum of $-3a^3b^3$, d, e, $-20c^2$ and $(d+e)$, when $a=1$, $b=2$ $c=3$ $d=-4$ $e=-5$

7. Find the sum of $-a^4(b-c)$, $-b^4(c-a)$ and $-c^4(b-a)$, when $a=2$ $b=3$, $c=4$

8. Find the value of $\{-(a^2-b^2)\}+\{-(a^3-b^3)\}+\{-(a^4-b^4)\}$, when $a=3$ $b=5$

9. Find the sum of $-x^3(y^2-z^2)$, $-y^3(z^2-x^2)$ and $-z^3(y^2-x^2)$, when $x=3$, $y=6$, $z=5$

10. Find the sum of $-\{a^4-b^4-c^4\}$, $-\{a^4-(b^4-c^4)\}$, $-\{a^4-b^4\times c^4\}$ and $-\{(a^4-b^4)\times c^4\}$, when $a=60$, $b=4$, $c=2$

30. The result when a negative quantity is added to a positive quantity. In the figure of Art 28 suppose a man starting from O travels to B in the first hour and from B to A in the second hour, then the distances travelled in the first and second hours will be respectively represented by $+5$ and -3, and therefore the distance from O at the end of the second hour will be represented by $(+5)+(-3)$ But the distance of the man from O at the end of the second hour (i e OA) is also evedently represented by $+2$ Hence we have $(+5)+(-3)=+2$, that is, $=+(5-3)$

Again, if the man starting from O travels to B in the 1st hour and from B to A' in the second hour, then the distances travelled by him in the 1st and 2nd hours will be respectively represented by $+5$ and -7, and therefore his distance from O at the end of the second hour will be represented by $(+5)+(-7)$ But his distance from O at the end of the second hour (i e OA') is also represented by -2 Hence we have $(+5)+(-7)=-2$ that is, $=-(7-5)$

Thus, generally speaking, we have $(+a)+(-b)=+(a-b)$ or $-(b-a)$ according as b is less or greater than a In other words, *if a positive and a negative quantity be added together, the sign of the result is positive or negative according as the absolute value of the negative quantity is less or greater than that of the positive quantity and the absolute value of the result is always equal to the difference between the absolute values of the quantities*

Cor. 1. Since $a+(-b)=-(b-a)$ when b is greater than a, *putting* $a=0$, we have $+(-b)=-b$; that is, *to add a negative quantity is the same as to subtract its absolute value, and conversely, to subtract a positive quantity is the same as to add a negative quantity having the same absolute value*

Note *Hence, there is no difficulty in finding the value of $a-b$ when b is greater than a, for $a-b$ can* ***always*** *be taken to be equivalent to $a+(-b)$, and this latter is equal to $-(b-a)$ when b is greater than a Thus $3-8=3+(-8)=-(8-3)=-5$*

Cor. 2. From Cor. 1, it is evident that the sum of any number of quantities can be expressed by writing down the quantities one after the other with their respective signs Thus $a-b+c-d$ means the same as $a+(-b)+c+(-d)$

Example 1. Find the value of $a-3b+2c-7d$, when $a=2$, $b=4$, $c=3$ $d=1$

$$\begin{aligned} a-3b+2c-7d &= a+(-3b)+2c+(-7d) \\ &= 2+(-12)+6+(-7) \\ &= -10+6+(-7) \\ &= -4+(-7)=-11 \end{aligned}$$

Example 2. Find the value of $a^2b-b^2c+c^2d-d^2a-bc^2$, when $a=1$, $b=2$, $c=3$, $d=4$

The given expression

$$\begin{aligned} &= (1^2\times 2)-(2^2\times 3)+(3^2\times 4)-(4^2\times 1)-(2\times 3^2) \\ &= 2-12+36-16-18 \\ &= -10+36-16-18 \\ &= 26-16-18 \\ &= 10-18=-8 \end{aligned}$$

EXERCISE 7.

1. Find the sum of 117 and -114

2. Find the sum of 218 and -223

3. Find the value of $x-y+z$, when $x=8$, $y=25$, $z=13$

4. Find the sum of $3x$, $-6y$, $2z$, u and $14v$, where $x=2$, $y=5$, $z=1$, $u=3$, $v=-2$

5. Find the value of $3m-5n+6q+r$ when $m=4$, $n=6$, $q=2$, $r=-8$

6. Find the sum of $-a^2c$, bd^2, $-cb^2$ and $-a^2d^2$, when $a=2$, $b=5$, $c=3$, $d=6$

7. Find the value of $2x^2y-3y^3x-5x^2y^2+x^3y^4$, when $x=y=2$

8. Find the value of $a^3-3a^2b+3ab^2-b^3$, when $a=3$ and $b=5$

9. Find the value of $m^5-5m^4n+10m^3n^2-10m^2n^3+5mn^4-n^5$ when $m=4$ and $n=6$

10. Find the value of $a^6-6a^5b+15a^4b^2-20a^3b^3+15a^2b^4-6ab^5+b^6$, when $a=3$ and $b=2$

31. When any number of quantities are added together, the result will be the same in whatever order the quantities may be taken.

Suppose a man starting from a place travels 6 miles to the north and then travels back along the same path 8 miles to the south Then his position at the end of the journey is 2 miles to the south of that place

Again if the man first travels 8 miles to the south and then travels 6 miles to the north, then also at the end of the journey he is still 2 miles to the south of the place

Thus we have $6+(-8)=(-8)+6$, each being equal to -2 or, more briefly, we have $6-8=-8+6$ and a similar result in other case

Hence generally $\qquad a-b=-b+a$

Again, since $\qquad 2-10+6=-8+6=-2,$

and also $\qquad -10+6+2=-4+2=-2,$

we have $\qquad 2-10+6=-10+6+2$ and a similar result in every other case

Hence, generally $\qquad a-b+c=-b+c+a$

Similarly, it may be shown that

$$a-b+c-d+e-f=a+c+e-b-d-f$$
$$=-b+c-d-f+e+a$$
$$=\&c \qquad \&c \qquad \&c$$

32. When any number of quantities are added together, they can be divided into groups and the result expressed as the sum of these groups.

We have $3-7-8+6-4+2$
$$=-4-8+6-4+2$$
$$=-12+6-4+2$$
$$=-6-4+2=-10+2=-8,$$

$$(3-7)+(-8+6)+(-4+2)$$
$$=-4+(-2)+(-2)=-8;$$

$$3+(-7-8+6)+(-4+2)$$
$$=3+(-9)+(-2)=-8,$$

$$3+(-7-8)+(6-4)+2$$
$$=3+(-15)+2+2=-8$$

Thus we have $3-7-8+6-4+2$
$$=(3-7)+(-8+6)+(-4+2)$$
$$=3+(-7-8+6)+(-4+2)$$
$$=3+(-7-8)+(6-4)+2,$$

and similar results in all other cases

Hence, generally, the expression $a+b-c-d+e-f+g$ can be put in any one of the following forms

(1) $(a+b)+(-c-d)+e+(-f+g)$

(2) $a+(b-c)-d+(e-f+g)$

(3) $(a+b-c)+(-d+e-f)+g$

(4) $a+(b-c-d)+e+(-f+g)$

(5) $(a+b-c-d)+(e-f+g)$

&c &c &c

Cor. 1. Conversely, we have $(a+b)+(-c-d)+e+(-f+g)$ $=a+b-c-d+e-f+g$ Hence, the following rule

To add together two or more algebraical expressions write down the terms in succession with their proper signs

Cor. 2. Since $a-b+c-d+e-f=a+c+e-b-d-f$ [Art 31] $=(a+c+e)+(-b-d-f)$, we have the following rule

When any number of quantities are to be added some of which are positive and other negative, collect the positive terms in one group and the negative terms in another and express the result as the sum of these two groups

Thus, $3-7+8-9+5-6=(3+8+5)+(-7-9-6)$
$=16+(-22)=-6$

Example 1. Simplify $5a-3b+2c-4a+2b-7c$

The given expression

$=5a-4a-3b+2b+2c-7c$ [Art 31]

$=(5a-4a)+(-3b+2b)+(2c-7c)$ [Art 32]

$=a+(-b)+(-5c)=a-b-5c$

Example 2. Simplify $3a^2b+5b^2c-6c^2a-10a^2b-7b^2c+8c^2a+4a^2b-b^2c+c^2a$

The given expression

$$=3a^2b-10a^2b+4a^2b+5b^2c-7b^2c-b^2c-6c^2a+8c^2a+c^2a$$

$$=(3a^2b-10a^2b+4a^2b)+(5b^2c-7b^2c-b^2c)+(-6c^2a+8c^2a+c^2a)$$

$$=(-7a^2b+4a^2b)+(-2b^2c-b^2c)+(2c^2a+c^2a)$$

$$=(-3a^2b)+(-3b^2c)+(3c^2a)$$

$$=-3a^2b-3b^2c+3c^2a$$

Note *In the process above, it must be noticed that when like terms are added together, the result is obtained by annexing the common letters to the sum of the numerical co-efficients For instance, we find that* $5b^2c-7b^2c-b^2c=-3b^2c$, *and evidently* -3 *is the sum of the co-efficients* 5, -7 *and* -1

Example 3. Add together $3a-2b+c$ and $-5d+6e-f$, and find the numerical value of the sum, when $a=2$, $b=1$ $c=3$ $d=4$, $e=7$ $f=5$

We have $(3a-2b+c)+(-5d+6e-f)$

$=3a-2b+c-5d+6e-f$

$=6-2+3-20+42-5$

$=(6+3+42)+(-2-20-5)=51+(-27)=24$

33. The ordinary rule for adding together compound expressions. Put the expressions under one another so that the different sets of like terms may stand in vertical columns and draw a line below the last expression then add up each vertical column and put the result below it The following examples will illustrate the method

Example 1. Add together $3a-5b+7c-9d$ $-8c+5a-3d+7b$, $4d+2c-a$ and $2b-3c+6d$

$$\begin{array}{lrl}
\text{The first expression} = & 3a-5b+7c-9d & \\
\text{The 2nd expression} = & 5a+7b-8c-3d & \text{[Art 31]} \\
\text{The 3rd expression} = & -a \quad +2c+4d & \\
\text{The 4th expression} = & 2b-3c+6d & \\
\hline
\text{The sum} = & 7a+4b-2c-2d &
\end{array}$$

Example 2. Find the numerical value of the sum of $20a^2b^3-25b^3c^4+d^7$ $-22a^2b^3+19b^3c^4-3d^7$ and $2a^2b^3+7b^3c^4+2d^7$, when $a=498$, $b=3$ $c=2$, $d=19$

$$\begin{array}{lr}
\text{The first expression} = & 20a^2b^3-25b^3c^4+\ d^7 \\
\text{The 2nd expression} = & -22a^2b^3+19b^3c^4-3d^7 \\
\text{The 3rd expression} = & 2a^2b^3+\ 7b^3c^4+2d^7 \\
\hline
\text{The sum} = & b^3c^4 \\
= & 3^3\times2^4=27\times16=432
\end{array}$$

EXERCISE 8.

Simplify the following

1. $2x+3y-z-3x-2y+z$
2. $9m^2-7n^2+5p^2+8n^2-4p^2-8m^2$
3. $8a^2-5a^2b-7a^2+5c^2-2a^2+6a^2b-4c^2$
4. $3abc-5c^2+6mnp^2-abc+7c^2-9mnp^2-2c^2$
5. $-7a^3b-5b^2c^2+10a^3b-3b^2c^2+3df-a^3b-b^2c^2-5df$
6. $8x^4y-5xyz-17x^4y+20x^2y^2-2xyz-35x^2y^2$ $+3x^4y-4xyz+5x^2y^2$
7. $9a^2bc-7b^2ca+5c^2ab+3b^2ca-5a^2bc-c^2ab$
8. $20x^3mn-23m^3nx+14n^3xm-37x^3mn-47n^3xm$ $+54m^3nx-8x^3mn+13n^3xm-15m^3nx+20n^3xm$

If $a=9$, $b=10$, $c=12$, $d=5$, $k=2$, $m=3$, $n=4$ $x=6$, $y=7$, $z=8$, find the numerical value of the sum of

9. $-k+3m+5n$ and $5d-4x-6y$

10. $5m-2y-7b-8c$ and $3d+x-10a$

11. $3k^2$, $-5m^2+7n^2$, $-2x+5b-c$ and $10d-7a$

12. $-2k+3m-4n$, $-d-5x+6y$ and $3z-5a-3b+5c$

13. $-km+az$ $bc-4md+y$, $-n^2-d^2+ab$ and $6kn-5y-7x+kmn$

14. k^3m-dnx, $by^2-ckm-x^2d$ $-bz+3a^2-2m^4d$ and $5n^2-7bdz+2ak^2-3b^2d$

15. $3m^4b-5a^2x-4b^2z$, $-13k^2b+4z^2d-7d^2n$, $-5c^2n+8b^2y+9d^3$ and $5az^2-7b^2c-4x^3b+8adn$

Add together

16. $a-2b+5c$ and $-7a+3b-8c$

17. $-3x+5y-9z$, $5x-3y+7z$ and $-2y+z$

18. x^3+3x^2-5x+4 $2x^3-6x^2+7x-8$, $-x^3+7x^2-2x+9$ and $5x^2+2$

19. $3a-2b+7c-8d$, $2c+6d-5a$ $3b+d-10c$, $c-4b+a$ and $-7d+5b$

20. $x^2+2xy+3y^2-x+y+2$, $-5x^2+y^2+2x-5$ $-3xy-7y^2+3y+1$ and $6x''+xy-x-4y+2$

If $a=5$, $b=4$, $x=8$, $y=7$, find the numerical value of

21. $(3x^3+5y^5-20a^2+49b^3)+(17a^2-27b^3-23x^3)+(-y^5+3b^3-3a^2)+(-23b^3-4y^5+7a^2+20x^3)$

22. $(10a^2-26x^5y^4+30x^3b^5+17a^6y^7)+(35x^5y^4+16a^6y^7-304a^2-28x^3b^5)+(-8a^6y^7-9x^5y^4-7x^3b^5)+(5x^3b^5-25a^6y^7+289a^2)$

23. $(2a^2-7a^2+9x^2-13y^2+15ab-21xy)+(5y^2+8b^2+17xy-6a^2-8ab-20x^2)+(13x^2-20ab+5a^2-16xy-10y^2-2b^2)+(13ab-2x^2+3b^2+23xy-a^2+18y^2)$

24. $(29abx-39bxy+49xya+59yab)+(29bxy+49yab-19abx-39xya)+(2abx-12xya+6bxy+24yab)+(3xya+1bxy-13abx-14yab)$

25. $(18a^2b^2-43b^2x^2+62x^2y^2-23abxy)+(39abxy+28b^2x^2-25a^2b^2-42x^2y^2)+(19b^2x^2+37a^2b^2-25abxy+35x^2y^2)+(9abxy-29a^2b^2-55x^2y^2-4b^2x^2)$

II. Subtraction.

34. Definition. Any quantity b is said to be subtracted from any other quantity a when a third quantity c is found such that the *sum* of b and c is equal to a. In other words, $c=a-b$ *when* c is such that $b+c=a$.

The quantity *from* which another quantity is subtracted is called the *minuend* and the *quantity subtracted* is called the *subtrahend*. The result is called the *difference* or the *remainder*. Thus if $a-b=c$, a is the minuend, b the subtrahend and c the remainder.

35. To subtract a positive quantity is the same as to add a negative quantity having the same absolute value, and to subtract a negative quantity is the same as to add a positive quantity having the same absolute value.

Since, $3+4=7$, we have $7-3=4=7+(-3)$
again, since $6+(-2)=4$, we have $4-6=-2=4+(-6)$

Hence, generally $a-b=a+(-b)$. i.e., *to subtract a positive quantity is the same as to add a negative quantity having the same absolute value.* [See Art. 30, Cor. 1.]

Since, $(-3)+5=2$ we have $2-(-3)=5$ [by definition] $=2+3$

similarly, since $(-6)+(-4)=-10$,

we have $(-10)-(-6)=-4=(-10)+6$

Thus, generally, since $(-b)+(a+b)=a$ we have $a-(-b)=a+b$, i.e., *to subtract a negative quantity is the same as to add a positive quantity having the same absolute value.*

Note. *One quantity a is said to be greater than another quantity b when $a-b$ is a positive quantity. Thus -4 is greater than -5 for $(-4)-(-5)=-4+5=1$. Similarly, $-5>-7$, $-10>-20$, and so on. Hence, in the series 5, 4, 3, 2, 1, 0, -1, -2, -3, -4, -5, -6, -7, -8, &c., each number is less than the one before it.*

36. Illustration. Suppose AD is a railway line

A O B C D

running from west to east, and A, O, B, C, D are stations on it such that $AO=OB=20$ miles, $BC=30$ miles and $CD=10$ miles. Suppose a man travels from O to C in two days

Then evidently, (the distance travelled on the first day) + (the distance travelled on the second day) = 50 miles, and hence, by definition, 50 miles − (the distance travelled on the first day) = the distance travelled on the second day

Now (i) if on the first day the man travels from O to B, *i e*, travels 20 miles towards the *east* of O, then on the second day he has to travel from B to C, a distance of 30 miles more towards the east, thus we have (50 miles) − (20 miles) = 30 miles

(ii) If on the first day the man travels from O to A, *i e*, travels a distance of 20 miles towards the *west*, then on the second day he must travel from A to C a distance of 70 miles *towards the east*, thus we have (50 miles) − (−20 miles) = 70 miles

(iii) Again, if on the first day the man travels from O to D, *i e*, a distance of 60 miles towards the east, then on the second day he must travel from D to C, *i e*, a distance of 10 miles *towards the west*, thus we have (50 miles) − (60 miles) = −10 miles

Hence, taking a mile as the unit of distance, we get the following results

$$\left.\begin{aligned} 50-\quad 20 &= \quad 30 \\ 50-(-20) &= \quad 70 \\ 50-\quad 60 &= -10 \end{aligned}\right\}$$

Example 1. Find the value of $a-b+c$, when $a=5$, $b=-2$, $c=-3$

$$\begin{aligned} a-b+c &= 5-(-2)+(-3) \\ &= 5+2-3=4 \end{aligned}$$

Example 2. Find the value of $-a-(-b)+c$, when $a=-2$, $b=-3$, $c=-4$

The given expression $= -a+b+c$

$$\begin{aligned} &= -(-2)+(-3)+(-4) \\ &= 2-3-4=-5 \end{aligned}$$

EXERCISE 9.

If $a=3$, $b=-5$ $c=-6$ $d=-8$, find the values of

1. $-a+b-c+d$ **2.** $a+(-b)+c-d$ **3.** $c-d-(-b)-a$
4. $c-(-d)+b-a$ **5.** $-(-a)+b-(-c)-d$

If $m=-47$, $n=50$, $x=-154$, $y=-234$, find the values of

6. $n-m-(-x)+y$ **7.** $-(-m)+y-(-n)-x$

8. $-(-x)+m-y-(-n)$ **9.** $-(-y)-m-x-(-n)$

10. $-(-n)-y-(-x)-m$

37. To prove that $a-(b+c)=a-b-c$,

and $a-(b-c)=a-b+c$.

Since $(b+c)+(a-b-c)=a$,

by definition, $a-(b+c)=a-b-c$

Again since $(b-c)+(a-b+c)=a$

$\therefore$ $a-(b-c)=a-b+c$*

Cor. Thus we arrive at the following rule for subtracting one algebraical expression from another: *Change the sign of every term of the subtrahend from + to − or from − to + as the case may be and then write down those terms in succession after the minuend.* Thus the result of subtracting $2a+3b-5c$ from $a-2b+c=a-2b+c-2a-3b+5c=-a-5b+6c$

Example 1. Subtract $-3a+2b-5c$ from $2a+b-8c$

The reqd result $=2a+b-8c+3a-2b+5c$

$=(2a+3a)+(b-2b)+(-8c+5c)$

$=5a+(-b)+(-3c)=5a-b-3c$

Example 2. Subtract $2a^2+3ab-5b^2$ from $-3a^2+2ab-4b^2$

The reqd result $=-3a^2+2ab-4b^2-2a^2-3ab+5b^2$

$=(-3a^2-2a^2)+(2ab-3ab)+(-4b^2+5b^2)$

$=-5a^2-ab+b^2$

38. The ordinary rule for subtracting one compound expression from another. Put the subtrahend below the minuend in such a way that the different sets of like terms may stand in vertical columns and draw a line below the subtrahend then supposing the sign of every

---

*When a, b, c are all positive quantities and a is greater than b and b is greater than c, the following proof is generally given of this result in most treatises on Algebra

If we subtract b from a, we get $a-b$, but we thus subtract too much from a for we have to subtract not b but a quantity which is less than b by c. Hence we must add c to this result, thus $a-(b-c)=a-b+c$

term of the subtrahend to be changed, write down the sum of each vertical column underneath it

Example 1. Subtract $-2x^2+3xy-y^2$ from $x^2-2xy+3y^2$

$$\begin{aligned} \text{The minuend} &= x^2-2xy+3y^2 \\ \text{The subtrahend} &= \underline{-2x^2+3xy-y^2} \\ \text{The remainder} &= -3x^2-5xy+4y^2 \end{aligned}$$

Note *It must be noticed that the signs of the terms of the subtrahend are not actually altered in the process, but they are* ***supposed*** *to be altered and the operation of combining each pair of like terms is performed mentally*

Example 2. Subtract $a^2-3ab+5x^2-y^2$ from $3x^2+2y^2-7a^2$

$$\begin{aligned} \text{The minuend} &= 3x^2+2y^2-7a^2 \\ \text{The subtrahend} &= \underline{5x^2-y^2+a^2-3ab} \\ \text{The remainder} &= -2x^2+3y^2-8a^2+3ab \end{aligned}$$

EXERCISE 10.

Subtract

1. $a-b+c$ from $3a+2b-c$
2. $2a-5b+4c$ from $-a-2b+8c$
3. $-x+y-z$ from $2x+3y-4z$
4. $5m^2-6m+3$ from $7m^2-8m-1$
5. $x^2-2y^2+3z^2$ from $3x^2-y^2+2z^2$
6. $4y^2+4xy-2x^2$ from $2y^2-3xy+x^2$
7. $-3a^2+2ab-7b^2$ from $a^2-5ab-8b^2$
8. $-2bc+6c^2-8xy$ from $5bc-c^2+2xy$
9. $2x^3-4x^2+7x+5$ from x^3-3x^2+6x+7

What is to be added to

10. $x+2y+z$ to make z?
11. $-2x+5y-4z$ to make $x+y+z$?
12. $3m^2+5m-6$ to make m^2?
13. $a^3+3a^2b+3ab^2+b^3$ to make a^3+b^3?
14. $a^4-2a^2b^2+b^4$ to make a^4+b^4?
15. What is to be subtracted from $a^3-3a^2b+3ab^2-b^3$ to make a^3-b^3?

39. Removal and Insertion of Brackets.

(*a*) The laws for the **removal** of brackets are

(i) If any number of terms be enclosed within a pair of brackets preceded by the sign + the brackets may be struck out as of no value ,

(ii) If any number of terms be enclosed with a pair of brackets preceded by the sign − the brackets may be removed provided that the sign of every term within the brackets be changed, namely + to −, and − to +

The reason is obvious, for any expression, included within brackets preceded by the sign +, has to be added to, whilst one enclosed within brackets preceded by the sign − has to be subtracted from what goes before

Thus $a-b+(c-d+e)=a-b+c-d+e$

whilst $a-b-(c-d+e)=a-b-c+d-e$

(*b*) The laws of **insertion** of brackets are

(i) Any number of terms in an expression may be enclosed within a pair of brackets, with the sign + prefixed

(ii) Any number of terms in an expression may be enclosed within a pair of brackets, with the sign − prefixed if the sign of every term put within the brackets be altered

Thus $a-b+c-d+e-f=a-b-(-c+d-e+f)$

Note *We often find brackets within brackets as in the expression* $2a-[3b-\{4c-(5d-6e)\}]$, *here it is meant that the expression within the braces* $\{\ \}$ *is to be subtracted from 3b and the result thus obtained is to be subtracted from 2a, whilst the expression within the braces is to be found by subtracting the expression within the parentheses ( ) from 4c*

When an expression of this kind is to be cleared of brackets, it is best for a beginner to remove first the innermost pair, then the innermost of those that remain, and so on, and lastly the outermost pair

Example 1. Simplify $a-\{b-(c-d)\}$

$$a-\{b-(c-d)\}=a-\{b-c+d\}$$
$$=a-b+c-d$$

Example 2. Simplify $a-[b-\{c-(d-e)\}-f]$

$$a-[b-\{c-(d-e)\}-f]=a-[b-\{c-d+e\}-f]$$
$$=a-[b-c+d-e-f]$$
$$=a-b+c-d+e+f$$

Example 3. Simplify $a+[-b-\{c-(d-\overline{e-f})-g\}-h]$

$$
\begin{aligned}
a+[-b-\{c-(d-\overline{e-f})-g\}-h] &= a+[-b-\{c-(d-e+f)-g\}-h] \\
&= a+[-b-\{c-d+e-f-g\}-h] \\
&= a+[-b-c+d-e+f+g-h] \\
&= a-b-c+d-e+f+g-h
\end{aligned}
$$

Example 4. Simplify $2a-[3a+\{4b-(2a-b)+5a\}-7b]$

$$
\begin{aligned}
\text{The given expression } &= 2a-[3a+\{4b-2a+b+5a\}-7b] \\
&= 2a-[3a+\{5b+3a\}-7b] \\
&= 2a-[3a+5b+3a-7b] \\
&= 2a-[6a-2b] \\
&= 2a-6a+2b=-4a+2b
\end{aligned}
$$

Example 5. Simplify $a-[-b-\{c-(d-\overline{e-f})\}]$, first removing [ ], then { }, then ( ), and last of all the vinculum

$$
\begin{aligned}
a-[-b-\{c-(d-\overline{e-f})\}] &= a+b+\{c-(d-\overline{e-f})\} \\
&= a+b+c-(d-\overline{e-f}) \\
&= a+b+c-d+\overline{e-f} \\
&= a+b+c-d+e-f
\end{aligned}
$$

Note *The expression within [ ] consists of two terms, namely, $-b$ and $-\{c-(d-\overline{e-f})\}$, hence, when this pair of brackets, which is preceded by the sign $-$, is removed, we get $b+\{c-(d-\overline{e-f})\}$ A similar reasoning applies to the removal of other brackets It must be noticed carefully that* ***only one pair of brackets is to be removed at a time***

Example 6. Simplify $[a-\{b-(c-d)\}]-[2a-\{3b+(2c-4d)\}]$

$$
\begin{aligned}
\text{We have } a-\{b-(c-d)\} &= a-\{b-c+d\} \\
&= a-b+c-d
\end{aligned}
$$

$$
\begin{aligned}
\text{and} \quad 2a-\{3b+(2c-4d)\} &= 2a-\{3b+2c-4d\} \\
&= 2a-3b-2c+4d
\end{aligned}
$$

Hence the given expression

$$
\begin{aligned}
&= [a-b+c-d]-[2a-3b-2c+4d] \\
&= a-b+c-d-2a+3b+2c-4d \\
&= -a+2b+3c-5d
\end{aligned}
$$

Example 7. Of the expression $a+b-c+d-e-f$ enclose the first three terms within a pair of brackets and the last three in another, each preceded by the sign $-$, and then put the last two terms of each of these bracketed expressions within an inner pair of brackets preceded by the sign $-$.

According to the given directions

$$a+b-c+d-e-f=-\{-a-b+c\}-\{-d+e+f\}$$
$$=-\{-a-(b-c)\}-\{-d-(-e-f)\}$$

EXERCISE 11.

Simplify

1. $2a-3b-(4a-6b)+(-2a+5b)$
2. $x+(-y+4x)-(-2x+3y)$
3. $-(5x-y)+(-3x+y)-(2y-6x)$
4. $3a-\{6a-(2b-a)\}$
5. $-a-\{2b-(6a+4b)\}$
6. $2a-\{5b-\overline{7b-2a}\}$
7. $3-\{5-(6-\overline{7-9})\}$
8. $-2-[-3-\{-4-(-5-6)\}]$
9. $-a-[-3b-\{-2a-(-a-4b)\}]$
10. $a-[2b-\{3c-(a-\overline{2b-3c})\}]$
11. $3x-[5y-\{10z-(5x-\overline{10y-3z})\}]$
12. $-a-[-b-\{-c-(-a-\overline{b-c})\}]$

Simplify the following expressions removing the brackets in the reverse order, *i.e.* the outermost first and the innermost last.

13. $2x-[5y-\{9x-(10y-4x)\}]$
14. $-5a-[3b-\{6a-(5b-7a)\}]$
15. $-7m-[3n-\{8m-(4n-10m)\}]$
16. $-2a-[-4b-\{-6c-(-8a-\overline{-10b-12c})\}]$
17. $-3x-[-5y-\{-7z-(-9x-\overline{-11y-13z})\}]$
18. $-2x-[-4y-\{-6z-(-3x-\overline{-5y-7z})\}]$
19. $-x-[-3y+\{-5z-(-2x+\overline{-4y-6z})\}]$
20. $-2a+[-5b-\{-8c+(-3a-\overline{-6b+9c})\}]$
21. $-x+[-5y-\{-9z+(-3x-\overline{-7y+11z})\}]$

Simplify

22. $\{2a-(3b-5c)\}-[a-\{2b-(c-4a)\}-7c]$

23. $[x-\{y-(z-x)\}-(y-z)]-[z-\{x-(y-z)\}]$

24. $[2a-(b-c)-\{3b-(2a-c)\}-\{-2a+(c-4b)\}]$
$-[-3b-(2a-4c)+\{6c-(2b-3a)\}-\{-5c+(6a-7b)\}]$

In the expression $a-b-c+d-m+n-x+y-z$

25. Include the 2nd, 3rd and 4th terms in a pair of brackets preceded by the sign $-$, and the 5th, 6th and 7th in a pair of brackets preceded by the sign $+$

26. Include all the terms after the 1st in a pair of brackets preceded by the sign $-$, and of the expression thus enclosed put the last four terms within a pair of brackets preceded by the sign $+$

27. Enclose the first five terms within a pair of brackets preceded by no sign and the last four within a pair of brackets preceded by the sign $-$, and then put the last three terms of each of these bracketed expressions within a pair of brackets preceded by the sign $-$

28. Enclose every three terms from the first in a pair of brackets preceded by the sign $-$ and then put the last two terms of each of these bracketed expressions within a pair of brackets preceded by the sign $-$

III. Multiplication.

40. Definition. One number is said to be multiplied by another when we do to the former what is done to unity to obtain the latter

Thus, since $4=1+1+1+1$ we must have

$$4\times x \text{ or } 4x=x+x+x+x$$

Similarly,
$$\left.\begin{aligned} 4\times5&=5+5+5+5 &&= 20\\ 3\times6&=6+6+6 &&= 18\\ 5\times3&=3+3+3+3+3 &&= 15\end{aligned}\right\}\quad \text{I}$$

$$\left.\begin{aligned} 3\times(-5)&=(-5)+(-5)+(-5) &&=-15\\ 4\times(-3)&=(-3)+(-3)+(-3)+(-3)&&=-12\\ 5\times(-4)&=(-4)+(-4)+(-4)+(-4)+(-4)&&=-20\end{aligned}\right\}\quad \text{II}$$

Again since $-4=-1-1-1-1$, we must have

$$(-4)\times x=-x-x-x-x$$

Similarly

$$\left.\begin{aligned}(-4)\times 5&=-5-5-5-5 &&=-20\\ (-3)\times 6&=-6-6-6 &&=-18\\ (-5)\times 3&=-3-3-3-3-3 &&=-15\end{aligned}\right\}\qquad \text{III}$$

Also

$$\left.\begin{aligned}(-3)\times(-5)&=-(-5)-(-5)-(-5)\\ &=5+5+5 &&=15\\ (-4)\times(-3)&=-(-3)-(-3)-(-3)-(-3)\\ &=3+3+3+3 &&=12\\ (-5)\times(-4)&=-(-4)-(-4)-(-4)-(-4)-(-4)\\ &=4+4+4+4+4 &&=20\end{aligned}\right\}\qquad \text{IV}$$

The number multiplied is called the **multiplicand** and the number by which it is multiplied is called the **multiplier**; the result is called the **product**.

EXERCISE 12.

From the definition of multiplication deduce the result

1. When 5 is multiplied by 3

2. When 6 is multiplied by 3

3. When 9 is multiplied by 4

4. When -8 is multiplied by 4

5. When -15 is multiplied by 3

6. When -13 is multiplied by 6

7. When 8 is multiplied by -3

8. When 7 is multiplied by -5

9. When 15 is multiplied by -3

10. When -9 is multiplied by -4

11. When -12 is multiplied by -5

12. When -16 is multiplied by -4

41. The Law of Signs. From the last article it is clear that if a and b are two whole numbers, we have

$$\left.\begin{aligned}(+a)\times(+b)&=+(ab)\\ (+a)\times(-b)&=-(ab)\\ (-a)\times(+b)&=-(ab)\\ (-a)\times(-b)&=+(ab)\end{aligned}\right\}$$

Thus, the product of two whole numbers is positive or negative according as the multiplicand and the multiplier have like or unlike signs

The same thing can be found when the numbers are fractional For instance, since $-\frac{2}{3}=-\frac{1}{3}-\frac{1}{3}$ *i e* since $-\frac{2}{3}$ is obtained by subtracting a third part of unity twice, to multiply any number x by $-\frac{2}{3}$ we must subtract a third part of x twice

Hence $\quad (-\frac{2}{3})\times x \quad =-\frac{x}{3}-\frac{x}{3}=-\frac{2x}{3}$

Similarly $\quad (-\frac{2}{3})\times\frac{4}{5} \quad =-\frac{4}{15}-\frac{4}{15}=-\frac{8}{15}$

$$(-\tfrac{2}{3})\times(-\tfrac{4}{5})=-(-\tfrac{4}{15})-(-\tfrac{4}{15})$$
$$=\tfrac{4}{15}+\tfrac{4}{15}=\tfrac{8}{15}$$

and so on

Hence we can enunciate the *Law of Signs* in a more general way thus The sign of the product of any two quantities is positive or negative according as the multiplicand and the multiplier have like or unlike signs Or, more briefly thus *Like signs produce + and unlike signs −*

Cor. Since $(-x)\times(-x)=x^2$ and also $(+x)\times(+x)=x^2$ we have $\sqrt{x^2}=\pm x$ Thus every algebraical quantity has got two square roots which are equal in absolute value but opposite in sign

Example. Simplify $(a^2b-cd)(c^2-d^2)$ when $a=-2$ $b=-3$, $c=-4$ $d=5$

Since $\quad a^2b=(-2)^2\times(-3)=4\times(-3)=-12$

and $\quad cd=(-4)\times 5=-20$

$\therefore \quad a^2b-cd=-12-(-20)=-12+20=8 \qquad (A)$

Also, since $\quad c^2=(-4)^2 \quad =16$

and $\quad d^2=(5)^2 \quad =25$

$c^2-d^2=16-25 \quad =-9 \qquad (B)$

Hence from (A) and (B) we have

$$(a^2b-cd)(c^2-d^2)=8\times(-9)=-72$$

EXERCISE 13.

Find the value of

1. $ab-cd$ when $a=-2$ $b=-3$ $c=-8$ $d=6$

2. $(x^2-y^2)b-axy$ when $a=1$ $b=-3$ $x=4$ $y=-5$

3. $3x^2y-3xy^2+xyz$ when $x=-1$ $y=-2$ $z=-7$

4. $(-a)b^2-cd^2+b(-c)^2$ when $a=5$, $b=-7$, $c=4$, $d=-3$

5. $-x^2(-c)+b^2(-y)+4a^3$ when $a=-2$, $b=-3$, $c=-1$, $x=5$, $y=6$

6. $a^2(b-c)+b^2(c-a)+c^2(a-b)$ when $a=-2$, $b=-5$, $c=-7$

7. $x^3(y-z)+y^3(z-x)+z^3(x-y)$ when $x=-3$, $y=8$, $z=-5$

8. $p^3(q^2-r^2)+q^3(r^2-p^2)+r^3(p^2-q^2)$ when $p=-3$, $q=-5$, $r=-7$

9. $a^3+b^3+c^3-3abc$, when $a=-12$, $b=-13$, $c=-15$

10. Show that $(a+b)^5=a^5+5a^4b+10a^3b^2+10a^2b^3+5ab^4+b^5$ when $a=3$, $b=-5$

42. To prove that $a\times b=b\times a$, *i.e.*, b multiplied by a gives the same result as a multiplied by b.

(i) First let a and b be any two positive integers

Place b units in a horizontal row and write down a such rows in such a manner that units in similar positions in the different rows may be in the same vertical column, thus

1	1	1	1	1	b times
1	1	1	1	1	b times
1	1	1	1	1	b times

to a lines

This being done evidently it may also be said that we have written down b columns, each containing a units

Now let us count up the total number of units thus written down

Since we have got a rows each containing b units, the total number of units = (the number in the 1st row) + (the number in the 2nd row) + (the number in the 3rd row) + + (the number in the ath row) $=b+b+b+$ to a terms $=a\times b$ (1)

Also since we have got b columns each containing a units, the total number of units = (the number in the 1st column) + (the number in the 2nd column) + (the number in the 3rd column) + + (the number in the bth column) $=a+a+a+$ to b terms $=b\times a$ (2)

Hence, from (1) and (2), we have $a \times b = b \times a$*,

i.e. b taken a times $= a$ taken b times

(ii) Next let a and b be two positive fractions, suppose $a = \frac{m}{n}$ and $b = \frac{p}{q}$, where m, n, p, q are positive integers

$$\text{Then } a \times b = \frac{m}{n} \times \frac{p}{q} = m \times \left\{ \left(\frac{p}{q} \right) \div n \right\}$$

$$= m \times \frac{p}{nq} = \frac{mp}{nq} \qquad \text{(I)}$$

$$\text{and } \quad b \times a = \frac{p}{q} \times \frac{m}{n} = p \times \left\{ \left(\frac{m}{n} \right) \div q \right\}$$

$$= p \times \frac{m}{qn} = \frac{pm}{qn} \qquad \text{(II)}$$

But m and p are positive integers therefore $mp = pm$ and similarly $nq = qn$

Hence, from (I) and (II), we have $a \times b = b \times a$ †

Thus it is established that for *all positive values* of a and b we must have $a \times b = b \times a$ (*A*)

---

*Since $ab = ba$, it does not matter much whether we read ab as a times b or b times a (i.e., as b multiplied by a or a multiplied by b), but *until the proposition of the present article has been proved* it seems expedient to stick to one and the same mode of interpreting it If a beginner is taught to read $7a$ as "7 times a" whilst 7×4 as "4 times 7" he is but unconsciously led to think that such expressions as ba and ab mean the same, and that consequently no amount of reasoning is necessary to establish the above proposition As a safeguard against this evil I have hitherto throughout taken $a \times b$ to mean "a times b" or 'b multiplied by a'

†We can illustrate $a \times b = b \times a$ when b and a are fractions as follows

Let us prove that $\frac{2}{3} \times \frac{4}{5} = \frac{4}{5} \times \frac{2}{3}$

$\frac{2}{3} \times \frac{4}{5}$ means that we have to divide $\frac{4}{5}$ of any thing into 3 equal parts and take 2 of those parts whilst $\frac{4}{5} \times \frac{2}{3}$ means that we have to divide $\frac{2}{3}$ of a thing into 5 equal parts and take 4 of those parts

Take a line AB 15 inches long, then $\frac{4}{5}$ of the line will be 12 inches, and evidently $\frac{2}{3}$ of 12 ins $= 8$ ins thus $\frac{2}{3} \times \frac{4}{5}$ of the line $= 8$ inches

Again, $\frac{2}{3}$ of the line is 10 inches, and $\frac{4}{5}$ of 10 inches $= 8$ inches

$\therefore \frac{4}{5} \times \frac{2}{3}$ of the line also $= 8$ inches

Hence, we have $\frac{2}{3} \times \frac{4}{5} = \frac{4}{5} \times \frac{2}{3}$ Similarly any other case may be illustrated

Cor. 1. From Art 41, we have $x\times(-y)=-(xy)$

and $(-y)\times x=-(yx)$, but $xy=yx$

$x\times(-y)=(-y)\times x$ (B)

Cor. 2. From Art 41 $(-x)\times(-y)=+xy$

and $(-y)\times(-x)=+yx$, but $xy=yx$

$(-x)\times(-y)=(-y)\times(-x)$ (C)

Hence, from (A) (B) and (C) we conclude that for *all values* of a and b $a\times b=b\times a$

EXERCISE 14.

Prove that

1. $4\times5=5\times4$ **2.** $6\times3=3\times6$ **3.** $7\times5=5\times7$

4. $4\times8=8\times4$ **5.** $9\times5=5\times9$

43. To prove that $(ab)\times c=a\times(bc)$ or, $=b\times(ac)$, *i.e.*, to multiply c by the product of a and b is the same as to multiply c first by either of them and then that result by the other.

Place b brackets in a horizontal row each containing c units and write down a such rows in such a manner that the brackets in similar positions in the different rows may be in the same vertical column, thus

[c] [c] [c] [c] b times
[c] [c] [c] [c] b times
[c] [c] [c] [c] b times

to a rows

This being done, it may also be said that we have written down b columns each containing a brackets

As we have got together $a\times b$ brackets and as each bracket contains c units, the total number of units$=(ab)\times c$ (α)

Again since we have got b brackets in a row each containing c units the number of units in a row$=bc$, and as there are a rows altogether therefore the total number of units $=a\times(bc)$ (β)

Again, since we have got a brackets in a column each containing c units, the number of units in a column$=ac$ and as there are b columns altogether therefore the total number of units$=b\times(ac)$ (γ)

Hence from (α), (β) and (γ) we have

$$(ab)\times c = a\times(bc) = b\times(ac)$$

Cor. From the results of the last article and this, we deduce that $abc=bca=cab$ For by the present article $abc=a\times(bc)$, and by the last article $a\times(bc)=(bc)\times a=bca$, hence we have $abc=bca$, and similarly $bca=cab$ Thus we have led to conclude that *the value of a product is the same in whatever order the factors may be taken* *

Note 1 *Although the factors of a product can be taken in any order it is always found convenient to place first the factor expressed in figures, and to put after it the factors expressed in letters in the alphabetical order of those letters Thus,* $c^3\times d\times 7\times b\times a^4$ *is written* $7a^4bcd$

Note 2 *We are now in a position to modify a little the definition of* ***co-efficient*** *given in Art 15 In an algebraical product one or more of the factors may be called the co-efficient of the remaining factors*

For instance, in 7abcd we may call 7ac as the co-efficient of bd, for 7abcd can be written as 7acbd and therefore by the definition alluded to, 7ac is the co-efficient of bd

44. To prove that $a^m\times a^n=a^{m+n}$, where m and n are any two positive integers.

N B From Art 42 we know that the quantity on either side of $\times$ *may be regarded as the multiplier and that on the other as the multiplicand Hence, we need not any longer observe the restriction we have hitherto placed upon the meaning of* $a\times b$

[See foot note, page 40]

Since $a^2=aa$

and $a^3=aaa$,

$$a^2\times a^3=(aa)\times(aaa)$$
$$=a\times a\times a\times a\times a \quad \text{[Art 43]}$$
$$=a^5=a^{2+3}$$

Again since $a^4=aaaa$

and $a^6=aaaaaa$

$$a^4\times a^6=(aaaa)\times(aaaaaa)$$
$$=a\times a\times a\times a\times a\times a\times a\times a\times a\times a \quad \text{[Art 43]}$$
$$=a^{10}=a^{4+6}$$

---

* The validity of the conclusion has been established only for three factors A general proof however has not been attempted as being too tedious for the class of students for whom the book is meant

Generally since $a^m = aaaa$ to m factors
and $a^n = aaaaa$ to n factors,

$$a^m \times a^n = (aaaa \text{ to } m \text{ factors}) \times (aaaaa \text{ to } n \text{ factors})$$
$$= aaaaaaaaa \text{ to } (m+n) \text{ factors}$$
$$= a^{m+n}.$$

Cor. 1. $a^m \times a^n \times a^p = a^{m+n+p}$ where m, n and p are positive integers.

For $a^m \times a^n = a^{m+n}$, $\therefore a^m \times a^n \times a^p = a^{m+n} \times a^p = a^{(m+n)+p}$
$= a^{m+n+p}$.

Cor. 2. $(a^m)^n = a^{mn}$ where m and n are positive integers.

For $(a^m)^n = a^m \times a^m \times a^m \times \ldots$ to n factors
$$= a^{m+m+m+\ldots \text{ to } n \text{ terms}}$$
$$= a^{mn}.$$

45. Applications of the principles established in the preceding articles.

Example 1. Show that $(-ab)^2 = a^2b^2$.

$$(-ab)^2 = (-ab) \times (-ab)$$
$$= (ab) \times (ab) \quad \text{[Art. 41.]}$$
$$= a \times b \times a \times b \quad \text{[Art. 43.]}$$
$$= a \times a \times b \times b \quad \text{[Cor., Art. 43.]}$$
$$= (aa) \times (bb) \quad \text{[Art. 43.]}$$
$$= a^2b^2 \quad \text{[Art. 44.]}$$

Example 2. Multiply $-5a^3b^2$ by $4a^5b^4$.

$$(-5a^3b^2) \times (4a^5b^4) = -\{(5a^3b^2) \times (4a^5b^4)\} \quad \text{[Art. 41.]}$$
$$= -\{5 \times a^3 \times b^2 \times 4 \times a^5 \times b^4\} \quad \text{[Art. 43.]}$$
$$= -\{5 \times 4 \times a^3 \times a^5 \times b^2 \times b^4\} \quad \text{[Cor., Art. 43.]}$$
$$= -\{20 \times (a^3a^5) \times (b^2b^4)\} \quad \text{[Art. 43.]}$$
$$= -20a^8b^6 \quad \text{[Art. 44.]}$$

Example 3. Simplify $(-2x^5y^4z) \times (4x^2y^7z^2) \times (-6xy^3z^4)$.

We have $(-2x^5y^4z) \times (4x^2y^7z^2)$
$$= -\{(2x^5y^4z) \times (4x^2y^7z^2)\}$$
$$= -\{2 \times x^5 \times y^4 \times z \times 4 \times x^2 \times y^7 \times z^2\}$$
$$= -\{2 \times 4 \times x^5 \times x^2 \times y^4 \times y^7 \times z \times z^2\}$$
$$= -\{8 \times (x^5x^2) \times (y^4y^7) \times (zz^2)\}$$
$$= -8x^7y^{11}z^3.$$

Hence the given expression

$$
\begin{aligned}
&=(-8x^7y^{11}z^3)\times(-6xy^3z^4)\\
&=(8x^7y^{11}z^3)\times(6xy^3z^4)\\
&=8\times x^7\times y^{11}\times z^3\times 6\times x\times y^3\times z^4\\
&=8\times 6\times x^7\times x\times y^{11}\times y^3\times z^3\times z^4\\
&=48\times(x^7x)\times(y^{11}y^3)\times(z^3z^4)\\
&=48x^8y^{14}z^7
\end{aligned}
$$

EXERCISE 15.

Show that

1. $(-a)\times 6b=-6ab$
2. $(4a)\times(-2b)=-8ab$
3. $-7x^7\times 8x^8=-56x^{15}$
4. $(-2b)\times(-10a)=20ab$
5. $(-7c)\times(-3ab)=21abc$
6. $10\times 35=25\times 14$
7. $15\times 75=5^3\times 3^2$
8. $(-a)^3=-a^3$
9. $(-ab)^3=-a^3b^3$
10. $(a^4b^2)^3=a^{12}b^6$
11. $(-a^3b^5)^2=a^6b^{10}$
12. $(-x)^5=-x^5$
13. $(-4x^2y^4)^2=16x^4y^8$

Multiply

14. $2x^2y$ by $-3x^5y^4$
15. $-7a^2b^3c$ by $-3abc^2$
16. $-5x^{12}y^8$ by $-8x^5y^{13}$
17. $-12x^8y^3z^2$ by $13x^7y^6z^4$
18. $-14xy^5z^8$ by $-10x^5y^2z^{12}$

Simplify

19. $(-x)^3\times(-2xy^2)^2\times(x^2y)^3$
20. $(-2a^2)\times(7a^4b^7)\times(5a^9b^5)$
21. $(-6x^5y^2z)\times(2z^4x^8y^5)\times(-4y^3z^2x^8)$
22. $(-3x^2y)\times(4zy^2x)\times(-x^3z^5y^4)\times(2zxy)$

46. Products of monomial expressions can be always found by the method illustrated in the last article, it is necessary, however when dealing with more complicated cases of multiplication, that such products should be found mentally Hence the student must get thoroughly accustomed to this kind of mental work for which an exercise is added below

Example 1. Write down the product of $3x^2$ and $-5xy$

$$(3x^2)\times(-5xy)=-15x^3y$$

Example 2. Write down the product of $-5a^2b$ and $-8ab^2$

$$(-5a^2b)\times(-8ab^2)=40a^3b^3$$

EXERCISE 16.

Write down the product of

1. $-2x^3$ and $5x^4$
2. $5a^3b$ and $-4ab$
3. $-3m^2n^5$ and $-7n^3m^5$
4. $3x^3y^5$ and $-6xy^2$
5. a^3b^2 and $-3a^4b$
6. $5mn^6$ and $-8m^7n$
7. $-10xyz^2$ and $-5xy^2z$
8. $4x^3y^3z$ and $-6xyz^3$
9. $-6x^2y^3z^4$ and $-8x^3y^2z$
10. $-5a^3b^5c^7$ and $-5a^2b^4c^6$
11. $3x^2yz^4$ and $-8xy^2z$
12. $-4abxy$ and $-8a^2xby^2$
13. $-7a^2b^2z^3$ and $-5abz$
14. $5a^4x^2y$ and $-12x^5y^4a^2$
15. $-14xy^4$ and $-5x^4yz$
16. $2abc^5$ and $-9a^7b^5c$
17. $-7a^3x^5y$ and $-9x^3ya^6$
18. $-8x^6y^2z^5$ and $-20y^5z^2x$
19. $-13a^8b^{13}c^{15}$ and $-5bc^5a^2$
20. $-7a^7xy^6z^2$ and $-16z^5x^2a^6y^3$

47. To prove that $a(b+c)$* $=ab+ac$.

Whatever b and c may be if a be a *positive integer* we have

$$a(b+c)=(b+c)+(b+c)+(b+c)+ \quad \text{to } a \text{ terms}$$
$$=(b+b+b+ \quad \text{to } a \text{ terms})$$
$$+(c+c+c+ \quad \text{to } a \text{ terms})$$
$$=ab+ac \qquad (1)$$

Hence, conversely $\dfrac{ab+ac}{a}=b+c=\dfrac{ab}{a}+\dfrac{ac}{a}$, that is, if p and q be any two quantities and r a *positive integer* then

$$\frac{p+q}{r}=\frac{p}{r}+\frac{q}{r}. \qquad (A)$$

Next suppose a is a positive fraction, *i e* suppose $a=\dfrac{m}{n}$, where m and n are positive integers

Then, $\dfrac{m}{n}(b+c)=m\times\dfrac{b+c}{n}$

[by the definition of multiplication]

$$=\frac{m(b+c)}{n}$$

---

*Every binomial expression can be put in the form $b+c$ For instance, the expression $2x^2-3y^2$, which can also be written as $(2x^2)+(-3y^2)$ is of the form $b+c$, $2x^2$ being regarded as b and $-3y^2$ as c

$$=\frac{mb+mc}{n} \quad [\text{by } (1)]$$

$$=\frac{mb}{n}+\frac{mc}{n} \quad [\text{by } (A)]$$

$$=\frac{m}{n}b+\frac{m}{n}c \qquad (2)$$

Hence from (1) and (2), for all *positive values* of a, we have $a(b+c)=ab+ac$ (3)

Next suppose a is any negative quantity, i e suppose $a=-x$ where x is any positive quantity

Then $(-x)(b+c)=-[x(b+c)]$

$=-(xb+xc)$ [by (3)]

$=-xb-xc=(-x)\,b+(-x)\,c$,

thus, for any *negative* value of a also, we have

$$a(b+c)=ab+ac \qquad (4)$$

Hence, from (3) and (4), for *all values* of a, b and c, we have

$$a(b+c)=ab+ac$$

Cor. 1. Conversely $ab+ac=a(b+c)$

Similarly, $xya^2+xyb^2=xy(a^2+b^2)$

Cor 2 Since $b-c=b+(-c)$, we have

$$a(b-c)=a[b+(-c)]=ab+a(-c)=ab-ac$$

Conversely $ab-ac=a(b-c)$ Hence, $2ax-2ay=2a(x-y)$

Cor 3. $a(b+c+d)=a\{b+(c+d)\}=ab+a(c+d)$

$=ab+ac+ad$

Similarly, $a(b+c+d+e+f+\ \ )=ab+ac+ad+ae+af+$

Thus, when any multinomial expression is multiplied by a monomial, the result is the sum of the products obtained by multiplying the different terms of the multinomial by the monomial

Conversely $ab+ac+ad+ae+\ \ =a(b+c+d+e+\ \ )$

Example 1. Multiply $2ab-3b^2$ by $5ab$

$5ab(2ab-3b^2)=5ab\{2ab+(-3b^2)\}$

$=5ab\times 2ab+5ab\times(-3b^2)$

$=10a^2b^2-15ab^3$

Example 2. Multiply $x^4-3x^3+5x^2-6x+4$ by $-6x^2$

$$\begin{aligned}(-6x^2)(x^4-3x^3+5x^2-6x+4)&=(-6x^2)\{x^4+(-3x^3)+5x^2+(-6x)+4\}\\&=(-6x^2)\,x^4+(-6x^2)(-3x^3)+(-6x^2)\,5x^2\\&\quad+(-6x^2)(-6x)+(-6x^2)\,4\\&=-6x^6+18x^5-30x^4+36x^3-24x^2\end{aligned}$$

N B The beginner is particularly recommended to work out at first each example in the method shown above, but after some practice he can safely do away with the intermediate steps and write down the result at once in the manner exemplified below

Example 3 Write down the product of

$-4a^4+5a^3b-6a^2b^2-8ab^3+9b^4$ and $-3a^2b^2$

$$\begin{array}{l}-4a^4+5a^3b-6a^2b^2-8ab^3+9b^4\\-3a^2b^2\\\hline 12a^6b^2-15a^5b^3+18a^4b^4+24a^3b^5-27a^2b^6\end{array}$$

Example 4. Simplify $2x^2(3x-2)+2x(2x+3)-6(x-3)$

We have $2x^2(3x-2)=6x^3-4x^2$

$2x(2x+3)=4x^2+6x$

$6(x-3)=6x-18$

Therefore the given expression

$$\begin{aligned}&=(6x^3-4x^2)+(4x^2+6x)-(6x-18)\\&=6x^3-4x^2+4x^2+6x-6x+18=6x^3+18\end{aligned}$$

Example 5. Simplify $3a(2a-5)-3a(a-6)$

Putting x for $2a-5$ and y for $a-6$ we have

$$\begin{aligned}3a(2a-5)-3a(a-6)&=3ax-3ay=3a(x-y)\\&=3a\{(2a-5)-(a-6)\}=3a(a+1)=3a^2+3a\end{aligned}$$

EXERCISE 17.

Multiply

1. $2x-y$ by $-x$ **2.** $a-2b+3c$ by $-5a$

3. $2x-3y$ by $4xy$ **4.** $2a^2-3b^2-c^2$ by abc

5. $x^2y-2xy^2-y^3$ by $-3xy$

6. $3a^2b^2-ab^2-5a^3+a^2b$ by $7b^2$

Write down the product of

7. $3a^2x-4ax^2+5ax$ and $-2a^2$

8. $-2m^3+3m^2n-5mn^2$ and $4mn$

9. $a^2bc-b^2ca+c^2ab$ and $-abc$

10. $x^2+y^2+z^2-yz-zx-xy$ and xyz

11. $-2c^2d+3d^3c-5cd^2-4c^2d^2$ and $-6c^2d^4$

12. $8a^4-6a^3b+5a^2b^2-4ab^3$ and $-2a^3b^3$

Simplify

13. $7x^3(x-2)-2x^2(x-3)-8x^2(1-2x)$

14. $x^2(y^2-z^2)+y^2(z^2-x^2)+z^2(x^2-y^2)$

15. $9x^3(x^3-2y^2)+5y^2(3x^3+y^2)+3y^2(x^3-10y^2)$

16. $x^3(x^3+2x^2+2x)-2x^2(x^3+2x^2+2x)+2x(x^3+2x^2+2x)$

17. $a^6b^3(a^6b^3-2a^4b^2+2a^2b)+2a^4b^2(a^6b^3-2a^4b^2+2a^2b)$
$+2a^2b(a^6b^3-2a^4b^2+2a^2b)$

18. $2a^9b^6(2a^9b^6+6a^6b^4+9a^3b^2)-6a^6b^4(2a^9b^6+6a^6b^4$
$+9a^3b^2)+9a^3b^2(2a^9b^6+6a^6b^4+9a^3b^2)$

19. $a^2(2x-3y)+a^2(3x+4y)-a^2(5x-2y)$

20. If $a=x^2-yz$, $b=y^2-zx$ and $c=z^2-xy$,
find the values of (i) $ax+by+cz$, (ii) $cx+ay+bz$

IV. Division.

48. Definition. One quantity a is said to be divided by another quantity b when a third quantity c is found such that $c\times b=a$ In other words, $a\div b=c$ when $a=b\times c$

Thus when $x=y\times z$, we have $x\div y=z$ and $x\div z=y$

When one quantity is divided by another, the former is called the *dividend* and the latter the *divisor*; the result is called the *quotient*

49. Fundamental Propositions.

(i) To prove that $a\div b\times b=a$.

If we denote $a\div b$ by x, we must have, by definition

$$x\times b=a$$

Hence $\quad a\div b\times b=x\times b=a$

(ii) To prove that $a \div b \div c = a \div bc$.

We have
$$\begin{aligned}(a \div b \div c) \times bc &= \{(a \div b) \div c\} \times c \times b\\ &= [\{(a \div b) \div c\} \times c] \times b\\ &= (a \div b) \times b \quad \text{[by the last result]}\\ &= a\end{aligned}$$

Hence, by definition, $a \div b \div c = a \div bc$

That is, *to divide any quantity successively by two others is the same as to divide it at once by their product*

Cor. Hence, $a \div b \div c = a \div c \div b$, for each of them $= a \div (bc)$

(iii) To prove that $a \div b = a \times \dfrac{1}{b}$.

We have $\qquad \dfrac{1}{b} \times b = 1 \div b \times b = 1 \qquad$ [by (i)]

Hence, $\qquad a \times \dfrac{1}{b} \times b = a \times \left(\dfrac{1}{b} \times b\right) \qquad$ [Art 43]

$$= a \times 1 = a,$$

i e $\qquad \left(a \times \dfrac{1}{b}\right) \times b = a$

Therefore, by definition, $a \div b = a \times \dfrac{1}{b}$.

Thus, *to divide one quantity by another is the same as to multiply the former by the reciprocal of the latter*

Cor. $a \div b \times c = a \times c \div b$

For $\qquad a \div b \times c = a \times \dfrac{1}{b} \times c$

$$= a \times c \times \frac{1}{b}, \qquad \text{[Cor, Art 43]}$$

and this latter $= a \times c \div b$

50. Law of Signs.

Since $\qquad a \times (-b) = -ab,$

by definition, $\left.\begin{aligned}(-ab) \div a &= -b\\ \text{and} \quad (-ab) \div (-b) &= a\end{aligned}\right\} \qquad$ I

Again since $\qquad (-a) \times (-b) = ab,$

$\left.\begin{aligned}ab \div (-a) &= -b\\ \text{and} \quad ab \div (-b) &= -a\end{aligned}\right\} \qquad$ II

It is evident also that $\left.\begin{aligned}ab \div a &= b\\ \text{and} \quad ab \div b &= a\end{aligned}\right\} \qquad$ III

Hence from I, II and III, we have the following law of signs in division. *When the dividend and the divisor have the same sign the quotient is positive and when they have different signs, the quotient is negative.* In other words *like signs produce +, and unlike signs −.*

51. Division of one monomial expression by another.

Let us examine a few particular cases.

(i) Since $3a^2b \times 5a^3b^2c = 15a^5b^3c$ we must have

$$(15a^5b^3c) \div (5a^3b^2c) = 3a^2b$$

$$\left.\begin{aligned} &\text{Thus, if the dividend} = 15a^5b^3c \\ &\qquad = 3 \times 5 \times a^3 \times a^2 \times b^2 \times b \times c \\ &\text{and the divisor} = 5a^3b^2c \\ &\text{we have the quotient} = 3a^2b \end{aligned}\right\} \quad \text{I}$$

(ii) Since $(-2a^{10}b^2cd) \times (-3a^5c^2) = 6a^{15}b^2c^3d$

we must have $6a^{15}b^2c^3d \div (-2a^{10}b^2cd) = -3a^5c^2$

$$\left.\begin{aligned} &\text{Thus, if the dividend} = 6a^{15}b^2c^3d \\ &\qquad = 2 \times 3 \times a^{10} \times a^5 \times b^2 \times c \times c^2 \times d, \\ &\text{and the divisor} = -2a^{10}b^2cd \\ &\text{we have the quotient} = -3a^5c^2 \end{aligned}\right\} \quad \text{II}$$

(iii) Since $(-5a^8b^5c^2d) \times (4b^3c^4) = -20a^8b^8c^6d$

we must have $(-20a^8b^8c^6d) \div (-5a^8b^5c^2d) = 4b^3c^4$

$$\left.\begin{aligned} &\text{Thus, if the dividend} = -20a^8b^8c^6d \\ &\qquad = -5 \times 4 \times a^8 \times b^5 \times b^3 \times c^2 \times c^4 \times d, \\ &\text{and the divisor} = -5a^8b^5c^2d \\ &\text{we have the quotient} = 4b^3c^4 \end{aligned}\right\} \quad \text{III}$$

Hence, from I, II and III, we are led to deduce the following rule for dividing one monomial expression by another.

Take away from the dividend all those factors which make up the divisor and to the remaining factors prefix the sign +, or no sign if the two expressions have the same sign and the sign −, if they have different signs.

Note *We have* $a^{12} \div a^7 = (a^5 \times a^7) \div a^7 = a^5$ $[= a^{12-7}]$

Similarly, $a^{20} \div a^9 = a^{11}$, $a^{21} \div a^{14} = a^7$; *and so on Hence, generally,* $a^m \div a^n, = a^{m-n}$, *where m and n are positive integers and* $m > n$

Example 1. Divide $18m^3n^2p$ by $-6m^2n^2p$

The dividend $= 18m^3n^2p$

$= 6 \times 3 \times m^2 \times m \times n^2 \times p$

The divisor $= -6m^2n^2p$

The quotient $= -3m$

Example 2. Divide $-24a^7b^3c$ by $-6a^4bc$

The dividend $= -24a^7b^3c$

$= -6 \times 4 \times a^4 \times a^3 \times b \times b^2 \times c$

The divisor $= -6a^4bc$

The quotient $= 4a^3b^2$

EXERCISE 18.

Divide

1. $16x^4$ by $-4x$ **2.** $-18x^6$ by $6x^2$

3. $-20a^7x^5$ by $-5a^3x^2$ **4.** $36x^{10}y^9$ by $12x^5y^4$

5. $-14a^4b^3c$ by $-7a^2bc$ **6.** $-20p^{12}q^8r^2$ by $10p^{10}q^6r^2$

7. $-70x^{16}y^9z$ by $-14x^{10}y^5$ **8.** $64a^{12}b^7c^5$ by $-8a^9b^7c^3$

9. $-81m^{13}n^{14}p^5$ by $27m^8n^6p^4$

10. $-69a^7b^4c^9$ by $-23a^5b^4c^7$

11. $25x^{20}y^3z^6$ by $-5x^{16}yz^5$

12. $-42a^{23}x^{23}y^9z^3$ by $-14a^{17}x^{18}y^5z$

13. a^{101} by a^{57} **14.** $28x^{205}$ by $-4x^{157}$

15. $56m^{307}$ by $-8m^{289}$ **16.** $-91a^{188}b^{209}$ by $13a^{97}b^{89}$

52. Division of Multinomial by a Monomial.

From Cor 3, Art 47, we have

$$a(b+c+d+e+f+\dots) = ab+ac+ad+ae+af+\dots$$

Hence, $(ab+ac+ad+ae+\dots) \div a = b+c+d+e+\dots$

$$= (ab \div a)+(ac \div a)+(ad \div a)+(ae \div a)+\dots$$

Thus, *to divide a multinomial expression by a monomial we have to divide each term of the dividend by the divisor and take the sum of those partial quotients for the complete quotient*

Example 1. Divide $4a^3x^2-6a^2x^3+10ax^4$ by $-2ax$

$$\text{The required quotient}=\frac{4a^3x^2-6a^2x^3+10ax^4}{-2ax}$$
$$=\frac{4a^3x^2}{-2ax}+\frac{-6a^2x^3}{-2ax}+\frac{10ax^4}{-2ax}$$
$$=-2a^2x+3ax^2-5x^3$$

Example 2. Divide $9x^5-4x^4a-2x^3a^2$ by $3x^3$

$$\text{The required quotient}=\frac{9x^5-4x^4a-2x^3a^2}{3x^3}$$
$$=\frac{9x^5}{3x^3}+\frac{-4x^4a}{3x^3}+\frac{-2x^3a^2}{3x^3}$$
$$=3x^2-\tfrac{4}{3}xa-\tfrac{2}{3}a^2$$

Note *After a little practice the student can safely do away with the (intermediate) step in each case and write down the quotient at once*

EXERCISE 19.

Divide

1. $3a^3b^2-2a^2b^3$ by a^2b^2 **2.** $2a^3b-3ab^3$ by $-ab$

3. $6a^4b^2-9a^2b^4$ by $3a^2b^2$ **4.** $12x^4y^2-9x^5y$ by $-3x^3y$

5. $14x^7y^3-21x^5y^7$ by $-7x^3y^3$

6. $4mn^3-12m^2n^2+16m^3n$ by $4mn$

7. $-3a^3x^4+6a^2x^5-9a^4x^3$ by $-3a^2x^3$

8. $12x^5-8x^3a^2+20ax^4$ by $-4x^3$

9. $10m^5n^4-15m^7n^2-20m^3n^6$ by $5m^3n^2$

10. $8p^4q^2-5p^3q^3-3p^2q^4$ by $-8p^2q^2$

11. $-14x^8y^5+21x^{10}y^3-28x^7y^6$ by $7x^7y^3$

12. $15a^4x^8-30a^7x^5-45a^6x^6$ by $20a^4x^5$

13. $-60x^4a^5-75x^3a^6+80x^5a^4$ by $-20x^3a^4$

14. $125m^6n^4p^2-175m^4n^6p^2-200m^2n^2p^8$ by $25m^2n^2p^2$

15. $-a^2b^4c^4x^4y^4z^2+2a^4b^2c^4x^2y^4z^4-3a^4b^4c^2x^4y^2z^4$ by $-a^2b^2c^2x^2y^2z^2$.

Miscellaneous Exercises. I

I

1. What number will represent an interval of 5 hours (i) if the unit of time be half an hour, (ii) if the unit of time be 10 hours ?

2. If x stands for 17 and y for 25 what does $x \sim y$ denote ?

3. Define 'Co-efficient' Distinguish between a *numerical* co-efficient and a *literal* co-efficient

What are the co-efficient of x^3 in $15x^3$, $2ax^3$ $7ab^2x^3$ and $16m^2pqx^3$?

4. Distinguish between $\sqrt{ab}$ and $\sqrt{a}b$ Find the value of $\sqrt{ab} \sim \sqrt{a}b$, when $a=9$ $b=4$

5. If a distance of half a mile to the north of a place be represented by 40, what will represent a distance of 11 yards to the south of it ?

6. State the result when a negative quantity is added to a positive quantity Hence deduce that $+(-b)=-b$

7. Define *subtraction* Hence deduce that $4-6=-2$ and that $5-(-3)=8$

8. Arrange the following numbers in descending order of magnitude 2 5 −3 7, −8 −1 9 −4 −12

II

1. If $a=4$, $b=5$, find the value of

(i) $ab-a\times b$ (ii) $45-ab$,

(iii) $74-7a$ (iv) $85-8b$

2. What does a^n mean ? Distinguish between a^n and n^a Find the value of $a^4-4a^3b+6a^2b^2-4ab^3+b^4$, when $a=7, b=5$

3. What is the relation between a and each of the following $\sqrt[3]{a}$ $\sqrt[5]{a}$, $\sqrt[7]{a}$ and $\sqrt[n]{a}$?

Find the value of $\sqrt{a^2-3d}\times\sqrt[3]{b^3-c^3-2e}$ when $a=8$ $b=7$ $c=6$, $d=5$ and $e=1$

4. What is meant by the *absolute value* of a positive or a negative quantity ? Illustrate this by an example

5. Add together $3x^2y$, $-8x^2y$, $-19x^2y$ and $17x^2y$ and find the numerical value of the sum when $x=4$, $y=5$

6. Write down the sum of $16x^4$, $-8xy^3$ $24x^2y^2$ y^4 and $-32x^3y$ and find its numerical value, when $x=4$, $y=5$

7. Subtract $4a-13b-25c$ from $17b-12c-19a$

8. Simplify $3x-[4y+\{2z-(x-5y+3z)\}]-(3x-7y)$

III

1. Express algebraically the following statements

(i) The result of multiplying the sum of a and b by c is the same as the result of dividing x by the product of y and z

(ii) The square of the sum of x and y is the same as the result of adding together the square of x, the square of y, and twice the product of x and y

(iii) If the cube root of the result of subtracting n from m be divided by the product of the cube of m and n, we get a quantity which is less than the sum of the square roots of x and y

(iv) Since a is greater than b, therefore three times a is greater than three times b

2. A B C, D, E, F G are a number of successive points on a straight line such that the distances AB, BC, CD, DE, EF, FG are respectively 3, 4, 6, 8 5 and 7 inches If DC be represented by 3, what numbers will represent DB, DE DF, DA and DG respectively?

3. State the result when one negative quantity is added to another Find the sum of $-a^3$ $-3a^2b$ $-3ab^2$ $-b^3$, when $a=6$, $b=4$

4. Show by a numerical example that when any number of quantities are added together the result is the same in whatever order the quantities may be taken

5. If $a=16$, $b=10$ $c=5$, $d=1$, find the value of

$$(a-b)(5\sqrt{a-b})+\sqrt{(a-b)(c+d)}$$

6. If $a=\frac{1}{2}$ $b=\frac{2}{3}$ prove that

$$\frac{a^5+b^5}{a+b}=a^4-a^3b+a^2b^2-ab^3+b^4$$

7. Add together $3a^2+4bc-x^2+10$ $2x^2-5a^2-15+6bc$ and $21-9bc-4a^2-10x^2$

8. Simplify $a-[5b-\{a-(3c-3b)+2c-(a-2b-c)\}]$

IV.

1. If $a=9$ find the value of

(i) $\sqrt{49}-\sqrt{4a}$, (ii) $\sqrt{49-\sqrt{4a}}$

2. Show by a numerical example that when any number of quantities are added together, they can be divided into groups and the result expressed as the sum of these groups

3. If $a=2$ $b=3$ $c=4$ find the value of

$$\frac{a-b+c}{a+b-c}+\frac{b-c+a}{b+c-a}+\frac{c-a+b}{c+a-b}.$$

4. Define an *Algebraical Expression* Distinguish between a *simple* expression and a *compound* expression

Is $42abx^2$ a simple or a compound expression? Give the names with illustrations of the different classes of compound expressions

5. If $x=2$, $y=3$, $a=6$, $b=5$, find the value of

$$\sqrt[3]{b(x+y)^2}+\sqrt[3]{(x+a)(b-2x)}+\sqrt[3]{x(b-y)^2}.$$

6. A certain sum is divided between A, B and C, B receives a pounds more than A, and C receives b pounds more than B, if A receives x pounds, find an expression for the whole sum divided

7. Add together $a^2-3ab-\frac{14}{21}b^2$ $2b^2-\frac{2}{7}b^3+c^2$ $ab-\frac{1}{3}b^2+b^3$ and $2ab-\frac{1}{7}b^3$

8. Reduce to its simplest form

$$\{2x^2-(y^2-xy)\}-\{y^2-(4x^2-y^2)\}+\{2y^2-(3xy-x^2)\}$$

V

1. What is meant by the *dimensions* and *degree* of a product? What is a *Homogeneous Expression*? Write down two trinomial homogeneous expressions, one of six dimensions and the other of seven

2. If you were asked to find the value of the expression $a\times b-c-d\times e+f-gh$, how would you proceed?

3. Define *factor* What are the *simple factors* of $2ab(a+b)$?

4. If $a=4$ and $x=2$, find the numerical value of

$$\frac{2ax^2}{(a-x)^2}-\frac{6\sqrt[3]{ax}}{a^3\sqrt{2a+4x}}-\frac{29x^2}{64a}.$$

5. Find the value of

$$(x^3-7x^2+6x+5)+(-3x+2x^3+4+5x^2)+(-11-4x^3+2x-7x^2)$$
$$+(9x^2+2+5x^3-4x) \text{ when } x=5$$

6. Prove that $a-(b-c)=a-b+c$ How is this generally proved when a b c are all positive quantities and a is greater than b and b is greater than c?

7. Simplify $2x-[(3x-9y)-\{(2x-3y)-(x+5y)\}]$

8. When is one number said to be multiplied by another? From the definition deduce the result when -8 is multiplied by -4

VI

1. Define the *power* of a number, and the *index* of the power, and illustrate them by a numerical example

2. If $a=16$, $b=10$, $x=5$, $y=1$, find the numerical value of $(a-y)\sqrt{24bx+x^2}+\sqrt{(a-x)(b+y)}$

3. Show that

$$a^3+b^3+c^3-3abc=(a+b+c)(a^2+b^2+c^2-ab-ac-bc)$$

(i) when $a=3$, $b=4$ $c=5$,

(ii) when $a=\frac{3}{2}$, $b=\frac{5}{2}$, $c=\frac{7}{2}$

4. State the propositions from which the following result may be deduced

$$a-b+c-d+e-f=(a+c+e)+(-b-d-f)$$

5. Illustrate clearly by an example that $40-(-15)=55$

6. Find the numerical value of the sum of $7x^3-25\sqrt{yz}+z^4$, $19\sqrt{yz}-3z^4-12x^3$ and $2z^4+5x^3+7\sqrt{yz}$ when $x=17$ $y=16$, $z=15$

7. State the operations indicated by the expression

$$5a-[4b-\{3c-(2d-7e)\}]$$

8. Find the value of

$$[(a^3+b^3+c^3+d^3)\{a+b-(c-a)\}+a^2b+c^2d]\times \{a^2-(b^2+c^2)+d^2\},\ \text{when } a=4,\ b=3,\ c=2,\ d=1$$

VII

1. Distinguish between (i) $a-bc$ and $a-b\times c$
(ii) a^4 and $4a$, (iii) $3\sqrt{a}$ and $\sqrt[3]{a}$,
(iv) $\sqrt{a+b}$ and $\sqrt{a}+b$, (v) $\sqrt{ab}$ and $\sqrt{a}b$

2. If $a=1$, $b=2$, $c=3$, $d=0$ find the value of

(i) $$\frac{a^2b+b^2c+c^2d+d^2a}{(a+b)(c+d)-\{(a-d)+(c-b)\}},$$

(ii) $$\sqrt[3]{b-a^3}+\sqrt[3]{4(c-a)}-\sqrt[4]{3(8a+5b+3c-2d)}$$

3. Show that the expressions

$(a+b+c)^3+a^3+b^3+c^3$, $(a+b)^3+(b+c)^3+(c+a)^3+6abc$ and $2a^3+3b^2(a+c)+2b^3+3c^2(a+b)+2c^3+3a^2(b+c)+6abc$ are equal to one another

(i) when $a=2$, $b=3$, $c=4$

(ii) when $a=7$, $b=4$, $c=1$

4. Simplify (i) $1-[1-\{1-(-\overline{1+x})\}]$

(ii) $3a-(b-2c)-\{a+c-(3a-b-2c)\}-(2a-3b+4c)$

5. Express algebraically the following statements

(i) That the product of the sum of two numbers multiplied by their difference is equal to the difference of the squares of the numbers

(ii) That the square of the sum of two numbers exceeds the sum of their squares by twice their product

6. Find the value of

$17a-5b-[7a-3b-\{4(a-b)-(2a+3b)\}]$, when $a=39$, $b=52$

7. If $V=5a+4b-6c$, $X=-3a-9b+7c$

$Y=20a+7b-5c$, $Z=13a-5b+9c$

calculate the value of $V-(X+Y)+Z$

[Madras University Matriculation Paper 1883]

8. From the sum of $a-\frac{1}{3}b+\frac{1}{4}c-\frac{1}{5}d$, $-\frac{1}{2}c+\frac{1}{3}a-\frac{1}{4}b+d$, $\frac{1}{4}d-\frac{1}{5}b+c-a$, $\frac{1}{6}a-\frac{3}{5}d+b-\frac{5}{8}c$ and $8a-6b+3c-4d$ subtract $\frac{13}{2}a-\frac{151}{30}b+\frac{9}{4}c-\frac{13}{4}d$

VIII

1. Prove that $a\times b=b\times a$, when a and b are any two positive integers

2. If M stands for $a(m+n)$ and N stands for $b(m-n)$ find the values of $\frac{M}{a}+\frac{N}{b}$ and $\frac{M}{a}-\frac{N}{b}$.

3. In the identity $c(a+b)=ca+cb$, substitute

(i) $m+n$ for c and find the value of the product
$$(m+n)(a+b),$$

(ii) $a+b$ for c and evaluate $(a+b)^2$

4. Simplify (i) $x(y-z)+y(z-x)+z(x-y)$.

(ii) $\frac{y-z}{yz}+\frac{z-x}{zx}+\frac{x-y}{xy}$.

5. Prove that

(i) $a^m - a^n = a^{m-n}$ where m and n are positive integers and $m > n$

and (ii) $a-b-c=a-c-b=a-bc$

6. If $a=3xy-yz-zx$, $b=3yz-xy-zx$ and

$c=3zx-xy-yz$, find the value of $\frac{a+b+c}{xyz}$.

7. Multiply
$\frac{3}{2}a^5b^{10}c^{15}x^8y^6z^4+\frac{15}{4}a^{10}b^{15}c^5x^6y^4z^2+\frac{5}{12}a^{15}b^5c^{10}x^4y^2$
by $24a^8b^5c^7x^2y^4z^6$

8. Divide $\frac{3}{2}a^{10}b^{15}c^{20}x^{12}y^{10}z^8+\frac{15}{4}a^{15}b^{20}c^{10}x^{10}y^8z^{12}$
$+\frac{9}{4}a^{20}b^{10}c^{15}x^8y^{12}z^{10}$ by $\frac{3}{4}a^{10}b^{10}c^{10}x^8y^8z^8$

CHAPTER IV

SIMPLE FORMULÆ AND THEIR APPLICATION

53. Definition. Any general result expressed in symbols is called a **formula.** In other words, a formula is the most general expression for any theorem respecting numerical quantities

54. Formula $(a+b)^2=(a^2+2ab+b^2)$.

$$\begin{aligned}[(a+b)^2 &= (a+b)(a+b)\\ &= a(a+b)+b(a+b)\\ &= a^2+2ab+b^2\,]\end{aligned}$$

That is *the square of the sum of any two quantities is equal to the sum of their squares plus twice their product*

Cor. $a^2+b^2=(a^2+2ab+b^2)-2ab$
$=(a+b)^2-2ab$

Example 1. Find the square of $2x+3y$

$$(2x+3y)^2=(2x)^2+2(2x)(3y)+(3y)^2$$
$$=4x^2+12xy+9y^2$$

Example 2. Find the square of $5x+4$

$$(5x+4)^2=(5x)^2+2(5x)4+4^2$$
$$=25x^2+40x+16$$

Example 3. Find the square of $4a^3+7b^4$

$$(4a^3+7b^4)^2=(4a^3)^2+2(4a^3)(7b^4)+(7b^4)^2$$
$$=16a^6+56a^3b^4+49b^8$$

Example 4. Find the square of $a+b+c$

$$(a+b+c)^2=\{a+(b+c)\}^2, \quad \text{[regarding } b+c \text{ as one term]}$$
$$=a^2+2a(b+c)+(b+c)^2$$
$$=a^2+2ab+2ac+b^2+2bc+c^2$$
$$=a^2+b^2+c^2+2ab+2ac+2bc$$

Example 5. Find the square of $a+b+c+d$

$$(a+b+c+d)^2=\{(a+b)+(c+d)\}^2, \quad \text{[regarding } a+b \text{ as one term and } c+d \text{ as another]}$$
$$=(a+b)^2+2(a+b)(c+d)+(c+d)^2$$
$$=(a^2+2ab+b^2)+2(ac+ad+bc+bd)+(c^2+2cd+d^2)$$
$$=a^2+b^2+c^2+d^2+2ab+2ac+2ad+2bc+2bd+2cd$$

Example 6. Simplify

$$(a+b-c)^2+2(a+b-c)(a-b+c)+(a-b+c)^2$$

Putting x for $(a+b-c)$ and y for $(a-b+c)$ we have the given expression $=x^2+2xy+y^2$

$$=(x+y)^2$$
$$=\{(a+b-c)+(a-b+c)\}^2$$
$$=(2a)^2=4a^2$$

Example 7. Find the value of $9x^2+30xy+25y^2$ when $x=15$, $y=-9$

The given expression $=(3x)^2+2(3x)(5y)+(5y)^2$
$=(3x+5y)^2$

But $3x+5y=3\times15+5\times(-9)=45-45=0$

$\therefore$ The given expression $=0$

EXERCISE 20.

Find the square of each of the following expressions

1. $x+4$ **2.** $3a+2$ **3.** $x+2y$

4. $2x+7y$ **5.** $3a+4b$ **6.** $5a+7b$

7. $ay+3bx$ **8.** a^2+2bc **9.** $3x^2+2y^2$

10. $4x^2+y^3$ **11.** $a+2b+3c$ **12.** $ab+bc+ca$

13. $2p+3q+4r$ **14.** $x^2+y^2+z^2$ **15.** $2x+3y+4z$

16. $x^2+y^3+z^4$ **17.** $x+y+2a+3b$ **18.** $3a+4b+c+2d$

19. $2a+x+4y+3z$ **20.** $4m+3n+3p+2q$

Simplify

21. $(x+y)^2+2(x+y)(x-y)+(x-y)^2$

22. $(x-y+z)^2+(y+z-x)^2+2(x-y+z)(y+z-x)$

23. $(2a-3b+4c)^2+(2a+3b-4c)^2+2(2a-3b+4c)(2a+3b-4c)$

24. $(5a-7b)^2+2(5a-7b)(9b-4a)+(9b-4a)^2$

25. $(2x-5y-3z)^2+(6y+3z-x)^2+2(2x-5y-3z)(6y+3z-x)$

Find the value of

26. $9x^2+12x+4$, when $x=-1$

27. $16x^2+64x+64$ when $x=-2$

28. $25m^2+40mn+16n^2$, when $m=-18$ and $n=23$

29. $49a^2+56ab+16b^2$, when $a=-7$ and $b=13$

30. $64a^2+16ac+c^2$ when $a=6$ and $c=-49$

31. $81x^2+18xz+z^2$ when $x=7$ and $z=-67$

32. $36p^2+132pq+121q^2$ when $p=12$ and $q=-7$

33. If $m+\frac{1}{m}=4$, show that $m^2+\left(\frac{1}{m}\right)^2=14$

55. Formula $(a-b)^2=a^2-2ab+b^2$.

$$\begin{aligned}[(a-b)^2&=(a-b)(a-b)\\&=a(a-b)-b(a-b)\\&=a^2-2ab+b^2\ ]\end{aligned}$$

That is *the square of the difference of any two quantities is equal to the sum of their squares minus twice their product*

Note *This formula is virtually included in the formula of the last article For,* $(a-b)^2=\{a+(-b)\}^2=a^2+2a(-b)+(-b)^2=a^2-2ab+b^2$.

Cor. 1. $a^2+b^2=(a^2-2ab+b^2)+2ab=(a-b)^2+2ab$

Cor. 2. Since $(a+b)^2=a^2+2ab+b^2$
and $(a-b)^2=a^2-2ab+b^2$

evidently we have

$$(a+b)^2=(a-b)^2+4ab \text{ and } (a-b)^2=(a+b)^2-4ab$$

Example 1. Find the square of $3a-4b$

$$\begin{aligned}(3a-4b)^2&=(3a)^2-2(3a)(4b)+(4b)^2\\&=9a^2-24ab+16b^2\end{aligned}$$

Example 2. Find the square of $x-y-z$

$$\begin{aligned}(x-y-z)^2&=\{x-(y+z)\}^2\\&=x^2-2x(y+z)+(y+z)^2\\&=x^2-2xy-2xz+y^2+2yz+z^2\\&=x^2+y^2+z^2-2xy-2xz+2yz\end{aligned}$$

Example 3 Find the square of $2x-3y-4z$

$$\begin{aligned}(2x-3y-4z)^2&=\{2x-(3y+4z)\}^2\\&=(2x)^2-2(2x)(3y+4z)+(3y+4z)^2\\&=4x^2-2(6xy+8xz)+\{(3y)^2+2(3y)(4z)+(4z)^2\}\\&=4x^2-12xy-16xz+9y^2+24yz+16z^2\\&=4x^2+9y^2+16z^2-12xy-16xz+24yz\end{aligned}$$

Example 4. Find the square of $a-b-c+d$

$$\begin{aligned}(a-b-c+d)^2&=\{(a-b)-(c-d)\}^2\\&=(a-b)^2-2(a-b)(c-d)+(c-d)^2\\&=(a^2-2ab+b^2)-2(ac-ad-bc+bd)\\&\qquad+(c^2-2cd+d^2)\\&=a^2-2ab+b^2-2ac+2ad+2bc-2bd\\&\qquad+c^2-2cd+d^2\\&=a^2+b^2+c^2+d^2-2ab-2ac+2ad\\&\qquad+2bc-2bd-2cd.\end{aligned}$$

Example 5. Simplify

$$(ax-by+cz)^2+(ax-by-cz)^2-2(ax-by+cz)(ax-by-cz)$$

Putting m for $(ax-by+cz)$ and n for $(ax-by-cz)$ we have the given expression

$$=m^2+n^2-2mn$$
$$=(m-n)^2$$
$$=\{(ax-by+cz)-(ax-by-cz)\}^2$$
$$=(2cz)^2=4c^2z^2$$

Example 6. Find the value of $9a^2-48ab+64b^2$ when $a=15$ and $b=6$

The given expression $=(3a)^2-2(3a)(8b)+(8b)^2$

$$=(3a-8b)^2=(45-48)^2$$
$$=(-3)^2=9$$

EXERCISE 21.

Find the square of each of the following expressions

1. $x-3$ **2.** $2x-5$ **3.** $3x-5y$

4. $ax-by$ **5.** $8m-3n$ **6.** $pm-qn$

7. p^2-mn **8.** x^2y-xy^2 **9.** x^3-2xz

10. $3a^3-5b^3$ **11.** $-xyz-abc$ **12.** x^2yz-y^2zx

13. $a^2x^4-b^2y^4$ **14.** $a-2b-2c$ **15.** $2x-3y-4z$

16. $3m-4n-5q$ **17.** $a^2-3b^2-5c^2$ **18.** $x-y-a-b$

19. $a-2x-3b-4y$ **20.** $90-1$ **21.** $120-3$

22. $300-2$ **23.** $1000-7$

Simplify

24. $(a+3b)^2-2(a+3b)(a-3b)+(a-3b)^2$

25. $(2a-4b+5c)^2+(2a+4b+5c)^2-2(2a-4b+5c)(2a+4b+5c)$

26. $(3a+5b+7c)^2+(7c-4a+5b)^2-2(3a+5b+7c)(7c-4a+5b)$

27. $(2x^2-y^2-5z^2)^2-2(2x^2-y^2-5z^2)(6z^2+2x^2-y^2)$
$+(6z^2+2x^2-y^2)^2$

28. $(ab-bc+ca)^2+(ab+4bc+2ca)^2$
$-2(ab-bc+ca)(ab+4bc+2ca)$

Find the value of

29. $a^2b^2-12abc+36c^2$, when $a=4$, $b=7$ and $c=5$

30. $x^2y^2-24xyz+144z^2$, when $x=7$, $y=9$ and $z=6$

31. $25(x+y)^2+z^2-10z(x+y)$ when $x=47$ $y=-22$ and $z=129$

32. $9c^2-42c(a+b)+49(a+b)^2$ when $a=-37$ $b=57$ and $c=45$

33. $64(7p-5q)^2-96(7p-5q)r+36r^2$ when $p=23$ $q=32$ and $r=46$

34. If $c-\dfrac{1}{c}=4$ show that $c^2+\left(\dfrac{1}{c}\right)^2=18$

56. Formula $(a+b)(a-b)=a^2-b^2$.

$$\left[\begin{aligned}(a+b)(a-b)&=a(a-b)+b(a-b)\\&=a^2-b^2\end{aligned}\right]$$

That is *the product of the sum and difference of any two quantities is equal to the difference of their squares*

Note *Conversely, $a^2-b^2=(a+b)(a-b)$ Hence we can always find the factors of an expression which is of the form a^2-b^2*

[*When one expression is the product of two or more expressions each of the latter is called a* ***factor*** *of the former*]

Example 1. Multiply $3x+5y$ by $3x-5y$

$$\begin{aligned}(3x+5y)(3x-5y)&=(3x)^2-(5y)^2\\&=9x^2-25y^2\end{aligned}$$

Example 2. Multiply $a+b-c$ by $a-b+c$

$$\begin{aligned}(a+b-c)(a-b+c)&=\{a+(b-c)\}\{a-(b-c)\}\\&=a^2-(b-c)^2\\&=a^2-(b^2-2bc+c^2)\\&=a^2-b^2+2bc-c^2\end{aligned}$$

Example 3. Multiply x^2+xy+y^2 by x^2-xy+y^2

$$\begin{aligned}(x^2+xy+y^2)(x^2-xy+y^2)&=\{(x^2+y^2)+xy\}\{(x^2+y^2)-xy\}\\&=(x^2+y^2)^2-(xy)^2\\&=x^4+2x^2y^2+y^4-x^2y^2\\&=x^4+x^2y^2+y^4.\end{aligned}$$

Example 4. Simplify $(a^2+ab+b^2)^2-(a^2-ab+b^2)^2$

The given exp $=\{(a^2+ab+b^2)+(a^2-ab+b^2)\}$
$\times\{(a^2+ab+b^2)-(a^2-ab+b^2)\}$
$=(2a^2+2b^2)\times 2ab$
$=2(a^2+b^2)\times 2ab$
$=4ab(a^2+b^2)$

Example 5. Find the value of $(9726854)^2-(9726849)^2$

The given exp $=(9726854+9726849)(9726854-9726849)$
$=19453703\times 5$
$=97268515$

Example 6. Resolve into factors $(a+b)^2-(c-d)^2$

The given exp $=\{(a+b)+(c-d)\}\{(a+b)-(c-d)\}$
$=(a+b+c-d)(a+b-c+d)$

Example 7. Resolve into factors $16a^4-81x^4$

The given exp $=(4a^2)^2-(9x^2)^2$
$=(4a^2+9x^2)(4a^2-9x^2)$

Again, $4a^2-9x^2=(2a)^2-(3x)^2$
$=(2a+3x)(2a-3x)$

Hence the given exp $=(4a^2+9x^2)(2a+3x)(2a-3x)$

EXERCISE 22.

Multiply together

1. $x+3$ and $x-3$ **2.** $5x+13$ and $5x-13$

3. $x+2a$ and $x-2a$ **4.** $ax+by$ and $ax-by$

5. $am+n^2$ and $am-n^2$ **6.** $xy+yz$ and $xy-yz$

7. x^2-2yz and x^2+2yz **8.** x^2y+xy^2 and xy^2-x^2y

9. $x+1$, $x-1$ and x^2+1 **10.** a^2+b^2, a^2-b^2 and a^4+b^4

11. $a+b+c$ and $a+b-c$ **12.** $a+b+c$ and $a-b-c$

13. m^2+mn+n^2 and m^2-mn+n^2

14. $x^2+2xy+2y^2$ and $x^2-2xy+2y^2$

15. $ax-by+cz$ and $ax+by-cz$

16. $-ax+by+cz$ and $ax+by+cz$

17. $b^2m-c^2n+a^2p$ and $b^2m+c^2n-a^2p$

18. $a^3-8b^3+27c^3$ and $a^3+8b^3-27c^3$

19. $a^2x^2-2ax+2$ and $a^2x^2+2ax+2$

20. $a^4x^4-a^2x^2+1$ and $a^4x^4+a^2a^2+1$

21. $m^2+\sqrt{2}\,mn+n^2$ and $m^2-\sqrt{2}\,mn+n^2$

22. $x^2-\sqrt{2}x+1$, $x^2+\sqrt{2}x+1$ and x^4-1

Simplify

23. $(a+b-c)^2-(a-b+c)^2$

24. $(a-2b+3c)^2-(a+2b-3c)^2$

25. $(x^2+xy+y^2)^2-(x^2-xy+y^2)^2$

26. $(x+y-a+b)^2-(x-y+a-b)^2$

27. $(2a+3b-5c+7d)^2-(2a-3b+5c-7d)^2$

Find the value of

28. $2345\times2345-2343\times2343$ **29.** $(53497)^2-(53487)^2$

30. $498567\times498567-498562\times498562$

Resolve into factors

31. $25x^2-36$ **32.** $9a^2-16c^2$ **33.** $16m^2-49n^2$

34. $4p^2-81q^2$ **35.** $a^2x^2-64b^2$ **36.** $36x^4-121y^4$

37. $49-64d^2$ **38.** $144c^2-25d^2$ **39.** $(a+b)^2-c^2$

40. $(a+2b)^2-25c^2$ **41.** $4x^2-(3a-4b)^2$

42. $a^2-(2b-3c)^2$ **43.** a^4-81b^4 **44.** $(x-y)^2-(a-b)^2$

45. $81x^4-625y^4$ **46.** $(4a+7b)^2-(3a-8b)^2$

47. $(3x+5y)^2-(2x-7y)^2$

48. $(a+2b-3c)^2-(a+b-c)^2$

49. $(2m+3n-5p)^2-(2n+3p)^2$

50. $(3x-4y+7z)^2-(2x-3y+5z)^2$

57. Formula $(a+b)^3=a^3+3a^2b+3ab^2+b^3$,
$\quad or=a^3+b^3+3ab(a+b)$.

$$\begin{aligned}[(a+b)^3&=(a+b)(a+b)^2\\
&=(a+b)(a^2+2ab+b^2)\\
&=a(a^2+2ab+b^2)+b(a^2+2ab+b^2)\\
&=a^3+3a^2b+3ab^2+b^3,\end{aligned}$$

and this latter$=a^3+3ab(a+b)+b^3$
$=a^3+b^3+3ab(a+b)]$

Cor. $a^3+b^3=\{a^3+b^3+3ab(a+b)\}-3ab(a+b)$
$$=(a+b)^3-3ab(a+b)$$

Example 1. Find the cube of $3a+5b$

$$(3a+5b)^3=(3a)^3+3(3a)^2(5b)+3(3a)(5b)^2+(5b)^3$$
$$=27a^3+3(9a^2)(5b)+3(3a)(25b^2)+125b^3$$
$$=27a^3+135a^2b+225ab^2+125b^3$$

Example 2. Simplify

$$(x-y)^3+(x+y)^3+3(x-y)^2(x+y)+3(x+y)^2(x-y)$$

[Calcutta University Entrance Paper 1876]

Putting a for $x-y$ and b for $x+y$, we have the given expression $=a^3+b^3+3a^2b+3b^2a$
$$=a^3+3a^2b+3ab^2+b^3$$
and $$=(a+b)^3$$
$$=\{(x-y)+(x+y)\}^3$$
$$=(2x)^3=8x^3$$

Example 3. If $a+b=5$ and $ab=6$, find the value of a^3+b^3

We have $a^3+b^3=(a+b)^3-3ab(a+b)$

and by the given condition
$$=5^3-3\times6\times5$$
$$=125-90=35$$

Example 4. If $x+\dfrac{1}{x}=p$, show that $x^3+\left(\dfrac{1}{x}\right)^3=p^3-3p$

Since $a^3+b^3=(a+b)^3-3ab(a+b)$
$$x^3+\frac{1}{x^3}=\left(x+\frac{1}{x}\right)^3-3x\,\frac{1}{x}\left(x+\frac{1}{x}\right)$$
$$=\left(x+\frac{1}{x}\right)^3-3\left(x+\frac{1}{x}\right)$$

Hence the reqd value $=p^3-3p$

Example 5. Find the cube of $p+q+r$

$$(p+q+r)^3=\{(p+q)+r\}^3$$
$$=(p+q)^3+3(p+q)^2r+3(p+q)r^2+r^3$$
$$=(p^3+3p^2q+3pq^2+q^3)+3(p^2+2pq+q^2)r$$
$$+3(p+q)r^2+r^3$$
$$=p^3+q^3+r^3+3p^2q+3pq^2+3p^2r+3pr^2+3q^2r$$
$$+3qr^2+6pqr$$

Example 6. Find the value of $x^3+9x^2y+27xy^2+27y^3$ when $x=5$ and $y=-2$

The given expression $=x^3+3x^2(3y)+3x(3y)^2+(3y)^3$

$$=(x+3y)^3=(5-6)^3$$
$$=(-1)^3=-1$$

EXERCISE 23.

Find the cube of

1. $x+3$ **2.** $2x+1$ **3.** $3a+b$ **4.** $4x+3y$

5. x^2+2y **6.** $xy+yz$ **7.** a^2b+c^2d **8.** $a+b+2c$

9. $2x+3y+z$ **10.** x^3+y^3

Simplify

11. $(3m+5n)^3+3(3m+5n)^2(2m-5n)$
$+3(3m+5n)(2m-5n)^2+(2m-5n)^3$

12. $(3x-8y)^3+(9y-2x)^3+3(x+y)(3x-8y)(9y-2x)$

13. $(3a-7b)^3+(10b-3a)^3+9b(3a-7b)(10b-3a)$

14. $(5x-2)^3+(3-4x)^3+3(x+1)(5x-2)(3-4x)$

15. $(3-7x)^3+(8x-1)^3+3(8x-1)(3-7x)(x+2)$

16. $(a-b+c)^3+(a+b-c)^3+6a\{a^2-(b-c)^2\}$

Find the value of a^3+b^3

17. When $a+b=6$ and $ab=7$

18. When $a+b=7$ and $ab=8$

19. If $a+\frac{1}{a}=3$ show that $a^3+\left(\frac{1}{a}\right)^3=18$

20. If $z+\frac{1}{z}=4$ find the value of $z^3+\left(\frac{1}{z}\right)^3$

Find the value of

21. $x^3+6x^2+12x+8$ when $x=-2$

22. $x^3+12x^2+48x+64$ when $x=-5$

23. $8a^3+36a^2b+54ab^2+27b^3+64$ when $a=-3$ and $b=2$

24. $x^3+18x^2+108x+351$, when $x=-11$

25. If $x+y=5$ show that $x^3+y^3+15xy=125$

26. If $a^2+b^2=c^2$, show that $a^6+b^6+3a^2b^2c^2=c^6$

27. If $p+q=2$, show that $p^3+q^3+6pq=8$

58. Formula $(a-b)^3=a^3-3a^2b+3ab^2-b^3$,
$\quad or=a^3-b^3-3ab(a-b)$.

$$\begin{aligned}[(a-b)^3 &= (a-b)(a-b)^2 \\ &= (a-b)(a^2-2ab+b^2) \\ &= a(a^2-2ab+b^2)-b(a^2-2ab+b^2) \\ &= a^3-3a^2b+3ab^2-b^3,\end{aligned}$$

and this latter $=a^3-3ab(a-b)-b^3$
$\qquad\qquad = a^3-b^3-3ab(a-b)$]

Cor. $a^3-b^3=\{a^3-b^3-3ab(a-b)\}+3ab(a-b)$
$\qquad\qquad =(a-b)^3+3ab(a-b)$

Example 1. Find the cube of $3x-4y$

$$\begin{aligned}(3x-4y)^3 &= (3x)^3-3(3x)^2(4y)+3(3x)(4y)^2-(4y)^3 \\ &= 27x^3-3(9x^2)(4y)+3(3x)(16y^2)-64y^3 \\ &= 27x^3-108x^2y+144xy^2-64y^3\end{aligned}$$

Example 2. Find the cube of $a-b-c$

$$\begin{aligned}(a-b-c)^3 &= \{(a-b)-c\}^3 \\ &= (a-b)^3-3(a-b)^2c+3(a-b)c^2-c^3 \\ &= (a^3-3a^2b+3ab^2-b^3)-3(a^2-2ab+b^2)c \\ &\qquad\qquad +3(a-b)c^2-c^3 \\ &= a^3-b^3-c^3-3a^2b+3ab^2-3a^2c+3ac^2 \\ &\qquad\qquad -3b^2c-3bc^2+6abc\end{aligned}$$

Example 3. Find the value of $27x^3-54x^2+36x-64$, when $x=2\frac{1}{3}$

The given expression $=(3x)^3-3(9x^2)\,2+3(3x)\,4-8-56$
$\qquad\qquad\qquad\qquad =(3x-2)^3-56$

Hence, the required value $=(7-2)^3-56$
$\qquad\qquad\qquad\qquad =125-56$
$\qquad\qquad\qquad\qquad =69$

EXERCISE 24.

Find the cube of

1. $x-2$ **2.** $2x-1$ **3.** $2-3a$
4. $3-4a$ **5.** $2a-3b$ **6.** $5m-4n$
7. $2x-5y$ **8.** $2a-b-c$ **9.** $2x-3y-z$
10. $p^2-q^2-r^2$

Simplify

11. $(a+2b)^3-3(a+2b)^2(a-2b)+3(a+2b)(a-2b)^2-(a-2b)^3$

12. $(3x-8y)^3-(2x-7y)^3-3(3x-8y)(2x-7y)(x-y)$

13. $(5x-8)^3-(3x-8)^3-6x(5x-8)(3x-8)$

Find the value of

14. $m^3-12m^2n+48mn^2-64n^3$, when $m=12$ and $n=3$

15. $27a^3-135a^2+225a-125$, when $a=4$

16. $8-9a+27a^2-27a^3$, when $a=3$

17. $216-144x+108x^2-27x^3$, when $x=3$

18. If $a-\dfrac{1}{a}=3$ find the value of $a^3-\left(\dfrac{1}{a}\right)^3$.

19. If $c-\dfrac{1}{c}=5$, find the value of $c^3-\left(\dfrac{1}{c}\right)^3$.

20. If $x-y=3$, show that $x^3-y^3-9xy=27$

21. If $p-2q=4$, show that $p^3-8q^3-24pq=64$

22. If $2a-3b=5$, show that $8a^3-27b^3-90ab=125$

59. Formula $(a+b)(a^2-ab+b^2)=a^3+b^3$.

$$
\begin{aligned}
[(a+b)(a^2-ab+b^2) &= a(a^2-ab+b^2)+b(a^2-ab+b^2)\\
&=(a^3-a^2b+ab^2)+(a^2b-ab^2+b^3)\\
&=a^3+b^3\,]
\end{aligned}
$$

Note *Conversely, $a^3+b^3=(a+b)(a^2-ab+b^2)$ Hence we can always resolve an expression into factors when it is of the form a^3+b^3*

Example 1. Multiply x^4-x^2+1 by x^2+1

Putting a for x^2 and b for 1 we have

$$x^4-x^2+1=(x^2)^2-x^2\cdot1+1^2=a^2-ab+b^2$$

Hence
$$
\begin{aligned}
(x^2+1)(x^4-x^2+1) &= (a+b)(a^2-ab+b^2)\\
&=a^3+b^3\\
&=(x^2)^3+1^3=x^6+1
\end{aligned}
$$

Example 2. Multiply $9x^2-12x+16$ by $3x+4$

Putting a for $3x$ and b for 4, we have

$$
\begin{aligned}
9x^2-12x+16 &= (3x)^2-(3x)\cdot4+4^2\\
&=a^2-ab+b^2
\end{aligned}
$$

Hence $(3x+4)(9x^2-12x+16)=(a+b)(a^2-ab+b^2)$

$$=a^3+b^3=(3x)^3+4^3$$
$$=27x^3+64$$

Example 3. Multiply $16a^2-20ab+25b^2$ by $4a+5b$

Putting x for $4a$ and y for $5b$ we have

$$16a^2-20ab+25b^2=(4a)^2-(4a)(5b)+(5b)^2$$
$$=x^2-xy+y^2$$

Hence, $(4a+5b)(16a^2-20ab+25b^2)$

$$=(x+y)(x^2-xy+y^2)$$
$$=x^3+y^3$$
$$=(4a)^3+(5b)^3$$
$$=64a^3+125b^3$$

Example 4. Resolve $a^3b^3+8c^3$ into factors

$$a^3b^3+8c^3=(ab)^3+(2c)^3$$
$$=(ab+2c)\{(ab)^2-(ab)(2c)+(2c)^2\}$$
$$=(ab+2c)(a^2b^2-2abc+4c^2)$$

EXERCISE 25.

Multiply

1. x^2-x+1 by $x+1$

2. $1-2x+4x^2$ by $1+2x$

3. $25p^2-5p+1$ by $5p+1$

4. $49a^2-28ab+16b^2$ by $7a+4b$

5. $64x^2-24xy+9y^2$ by $8x+3y$

6. $a^2b^2-4abc+16c^2$ by $ab+4c$

7. $a^2x^2-5abx+25b^2$ by $ax+5b$

8. $25a^2-45ab+81b^2$ by $5a+9b$

Resolve into factors

9. a^3+1 **10.** x^3+8 **11.** $8x^3+1$

12. $27a^3+8$ **13.** $8m^3+64$ **14.** $64p^3+125$

15. $8x^3+216y^3$ **16.** $27a^3+343y^3$ **17.** $216a^3x^3+y^3$

18. $27a^3b^3+64x^3y^3$ **19.** $729a^3b^3c^3+1000x^3y^3z^3$

20. $1331a^3b^6x^9+729c^3y^6z^9$

60. Formula $(a-b)(a^2+ab+b^2)=a^3-b^3$.

$$[(a-b)(a^2+ab+b^2)=a(a^2+ab+b^2)-b(a^2+ab+b^2)$$
$$=(a^3+a^2b+ab^2)-(a^2b+ab^2+b^3)$$
$$=a^3-b^3\ ]$$

Note *Conversely,* $a^3-b^3=(a-b)(a^2+ab+b^2)$ *Hence, we can always resolve into factors an expression which is of the form* a^3-b^3

Example 1. Multiply $4a^2b^4+2ab^2+1$ by $2ab^2-1$

$$(2ab^2-1)(4a^2b^4+2ab^2+1)$$
$$=(2ab^2-1)\{(2ab^2)^2+(2ab^2)1+1^2\}$$
$$=(2ab^2)^3-1^3=8a^3b^6-1$$

Example 2. Resolve $64x^6-a^3y^6$ into factors

$$64x^6-a^3y^6=(4x^2)^3-(ay^2)^3$$
$$=(4x^2-ay^2)\{(4x^2)^2+(4x^2)(ay^2)+(ay^2)^2\}$$
$$=(4x^2-ay^2)(16x^4+4ax^2y^2+a^2y^4)$$

EXERCISE 26.

Multiply

1. $1+2x+4x^2$ by $1-2x$ **2.** x^2+3x+9 by $x-3$

3. $16a^2+4a+1$ by $4a-1$

4. $x^4+2x^2yz+4y^2z^2$ by x^2-2yz

5. $9m^2+6mnq+4n^2q^2$ by $3m-2nq$

Resolve into factors

6. $125a^3-1$ **7.** $343x^3-8y^6$ **8.** $216k^3-125l^3$

9. $1-512k^3$ **10.** $729m^3-64a^3n^6$

61. Formula $(x+a)(x+b)=x^2+(a+b)x+ab$.

$$[(x+a)(x+b)=x(x+b)+a(x+b)$$
$$=x^2+(a+b)x+ab\ ]$$

Note *It is easy to see that the above formula includes the following results*

$$\left.\begin{array}{ll}(1) & (x-a)(x-b)=x^2-(a+b)x+ab\\ (2) & (x-a)(x+b)=x^2+(b-a)x-ab\\ (3) & (x+a)(x-b)=x^2+(a-b)x-ab\end{array}\right\}$$

For instance, $(x-a)(x-b)=\{x+(-a)\}\{x+(-b)\}$

$$=x^2+\{(-a)+(-b)\}x+\{(-a)\times(-b)\}$$
$$=x^2-(a+b)x+ab$$

Similarly, the truth of the other results can be proved, which is left as an exercise for the student

Hence, we can express the formula more clearly as follows $(x+a)(x+b)=x^2+$(algebraic sum of a and b)$x+$(product of a and b)

Example 1. Write down the product of $x+3$ and $x+4$

Since $3+4=7$ and $3\times4=12$, the required product $=x^2+7x+12$

Example 2. Write down the product of $x-7$ and $x+4$

Since $-7+4=-3$ and $(-7)\times4=-28$, the required product $=x^2-3x-28$

Example 3. Write down the product of $x+5$ and $x-9$

Since $5-9=-4$ and $5\times(-9)=-45$, the required product $=x^2-4x-45$

Example 4. Write down the product of $x-2$ and $x+7$

Since $-2+7=5$ and $(-2)\times7=-14$ the required product $=x^2+5x-14$

Example 5. Write down the product of $x-5$ and $x-8$

Since $-5-8=-13$ and $(-5)\times(-8)=40$, the required product $=x^2-13x+40$

EXERCISE 27.

Write down the product of

1. $x+1$ and $x+2$ **2.** $x+2$ and $x+9$

3. $x-5$ and $x+6$ **4.** $x-3$ and $x-11$

5. $a-11$ and $a+16$ **6.** $m-7$ and $m+19$

7. $p+13$ and $p-11$ **8.** $p+12$ and $p-17$

9. $x-4$ and $x+9$ **10.** $x-5$ and $x-10$

11. $x-12$ and $x+5$ **12.** $k-13$ and $k+2$

13. $a+5$ and $a+14$ **14.** $m-14$ and $m+6$

15. $x-5$ and $x-13$ **16.** $x+7$ and $x+12$

17. $a-3$ and $a-11$ **18.** $x+4$ and $x-13$

19. $m+5$ and $m-16$ **20.** $x-8$ and $m-10$

21. $a+6$ and $a-12$ **22.** $m-7$ and $m+13$

23. $x-10$ and $x-16$ **24.** $x+5$ and $x-18$

25. $x-16$ and $x+10$

CHAPTER V

SIMPLE EQUATIONS

62. Definitions. Any two expressions connected by the sign of equality constitute an **equation**, and each of the expressions thus connected is called a **side** or **member** of the equation.

The term equation, however is hardly used in this extended sense. When one expression is put equal to another the equality may hold *either* for all values of the letters involved, as in $(a+b)(a-b)=a^2-b^2$, *or* for some particular values of the letters only as in $4x=8$, (which is true only when $x=2$). The latter class of equations alone are called *equations* (more correctly *Equations of Condition*), whilst any equation of the former class is called an **Identity** (or an Identical Equation).

Thus $(x+1)+(2x+3)=3x+4$ is an *Identity*,

whereas $(x+1)+(x+3)=3x+2$ is an *Equation*,

the former being true for *all values* of x and the latter *only when* $x=2$.

The letter to which a particular value or values must be given in order that an equation may be true, is called the *unknown quantity*. It is usually represented by one of the last letters of the alphabet x, y, z, &c.

Any particular value of the unknown quantity, for which an equation is true, is said to **satisfy** the equation and is called a **root** or a **solution** of the equation.

To **solve** an equation is to find its root or roots.

An equation containing only one unknown quantity, is said to be an equation of the first degree or a **simple equation**, when the unknown quantity occurs only in the *first* power

63. Axioms. The process of solving an equation is primarily based upon the following axioms

(1) If to equals the same quantity, or equal quantities be added, the sums are equal.

(2) If from equals the same quantity, or equal quantities be taken, the remainders are equal

(3) If equals be multiplied by the same quantity, or by equal quantities, the products are equal

(4) If equals be divided by the same quantity, or by equal quantities the quotients are equal

Cor. 1. From axioms (1) and (2), we deduce an important principle which is of great use in solving equations, and which may be ennunciated as follows

Any term may be transposed from one side of an equation to the other by simply changing its sign

For, let $x-a=b+c$,

then adding a to both sides, we must have

$$x-a+a=b+c+a \qquad \text{[Axiom (1)]}$$

or $x=b+c+a$,

again, subtracting c from both sides we have

$$x-a-c=b+c-c \qquad \text{[Axiom (2)]}$$
$$=b$$

Thus $-a$, removed from the left side, appears as $+a$ on the right, and $+c$ removed from the right side appears as $-c$ on the left

Similarly if $x-a=b-c+d$, we have $x-a-b+c-d=0$

Such removal of terms is called **Transposition.**

Cor. 2. *The sign of every term of an equation may be changed without destroying the equality*

For let $x-a=b+c$,

then $(x-a)\times(-1)=(b+c)\times(-1)$ [Axiom (3)]

or $-x+a=-b-c$

64. Simple Examples. We shall now work out some examples illustrating the general method of solving a simple equation by the application of the foregoing principles The unknown quantity will always be denoted by x

Example 1. Solve $18x=54$

N B The question may be otherwise put as follows "If $18x=54$, what is the value of x ?"

Since, $18x=54$,

dividing both sides by 18, we get

$$\frac{18x}{18}=\frac{54}{18} \qquad \text{or,} \qquad x=3$$

Thus the required value of x is 3

Example 2. Solve $3x+5=x+19$

N B The question may be otherwise put as follows "If $3x+5=x+19$, what is the value of x ?"

Since $3x+5=x+19$,

by transposition, we must have

$$3x-x=19-5, \quad \text{or,} \quad 2x=14,$$

and therefore (dividing both sides by 2)

$$x=7 \qquad \text{[Axiom (4)]}$$

Thus the required value of x is 7

Example 3. Solve the equation $-11x+2(3-x)=32$

Removing the brackets, we get

$$-11x+6-2x=32$$

or, $-13x+6=32$,

or, $-13x=32-6$ [by transposition]

or $-13x=26$

Multiplying both sides by -1,

$$(-1)\times(-13x)=(-1)\times 26$$

or $13x=-26$,

dividing both sides by 13

$$x=-\tfrac{26}{13}, \text{ i e}, -2$$

Thus the required value of x is -2

Example 4. Solve $(x+2)(3x+4)-6x=10+(3x+2)(x+1)$

The left side $=3x^2+10x+8-6x$
$=3x^2+4x+8$,

and the right side $=10+3x^2+5x+2$
$=3x^2+5x+12$

Hence

$$3x^2+4x+8=3x^2+5x+12$$

Removing $3x^2$ from both sides we have

$$4x+8=5x+12 \qquad \text{[Axiom (2)]}$$

Hence by transposition

$$4x-5x=12-8$$

or, $\quad -x=4$

and $\quad x=-4 \qquad$ [Cor 2, last article]

Thus the required value of x is -4

Note *The student can easily see for himself that when x has this value, each side of the given equation becomes equal to 40*

Example 5. Given $\frac{x}{6}+5=\frac{x}{3}+\frac{x}{4}$, find x

Since, $\quad \frac{x}{6}+5=\frac{x}{3}+\frac{x}{4}$,

multiplying both sides by 12, (which is the L C M of the denominators) we have

$$12\left(\frac{x}{6}+5\right)=12\left(\frac{x}{3}+\frac{x}{4}\right) \qquad \text{[Axiom (3)]}$$

or, $\quad 2x+60=4x+3x=7x$

Hence by transposition,

$$2x-7x=-60$$

or, $\quad -5x=-60$

and therefore (dividing both sides by -5),

$$x=12$$

Thus the required root is 12

EXERCISE 28.

Solve the following equations

1. $4x=16$ **2.** $3x=-15$ **3.** $7x=-28$

4. $-5x=25$ **5.** $\frac{x}{5}=-1$ **6.** $\frac{-x}{3}=20$

7. $3x+5(2-x)=-16$ **8.** $5(1-x)+3(2-x)=-29$

9. $4(2-x)+2(3-2x)=30$ **10.** $7(3-2x)+5(x-1)=31$

11. $4x+3=2x+5$ **12.** $3x+2=x+6$

13. $5x-6=2x+3$ **14.** $15x-9=11x-25$

15. $4(x-3)=2(x-6)$ **16.** $2(x-15)=5(x-11)+4.$

17. $19-3x=5x+35$

18. $3(x-2)+7(2x-3)=5(1-2x)-59$

19. $13x-4(5x-8)+17=0$

20. $14(x-4)+3(x+5)=6(7-2x)+4$

21. $8(2x-7)-9(3x-14)=15$

22. $3x-13(2x-13)=4x-20$

23. $49+13(5x+27)=8(5+x)-3x$

24. $16-5(7x-2)=13(x-2)+4(13-x)$

25. $8x+5(x+7)+9(2x+23)-3(x+6)=0$

26. $(x-7)(4x-29)=(2x-5)(2x-17)+1$

27. $(3x+2)(2x-6)=(4-3x)(1-2x)-10$

28. $(3x+5)(6x-7)=(3x+2)(9x-13)-(3x+1)(3x-1)$

29. $(x+2)(2x+5)=2(x+1)^2+13$

30. $(x+1)(4x-7)-(x-1)(x+5)=3(x+2)^2+5$

31. $\frac{x}{2}+5=\frac{x}{3}+7$ **32.** $\frac{x}{6}-\frac{x}{5}=\frac{x}{15}-\frac{x}{3}+7.$

33. $\frac{x}{2}-\frac{x}{3}+\frac{x}{4}=2-\frac{x}{6}+\frac{5x}{12}$

CHAPTER VI

PROBLEMS LEADING TO SIMPLE EQUATIONS

65. Symbolical Expression. The chief difficulty in solving an algebraical problem lies in expressing correctly the condition of the problem by means of symbols The student should, therefore, be first of all introduced to this art before the solution of any problem is presented to him The following examples will serve as illustrations

Example 1. If a man earns x rupees per month, how many four-anna pieces will he earn in half a month ?

Since 1 rupee = 4 four-anna pieces
x rupees = $4x$ four-anna pieces

Clearly therefore the man earns $4x$ four-anna pieces per month

Hence, the number of four-anna pieces earned in half a month $= \frac{1}{2}$ of $4x = 2x$

Example 2. If an insect creeps up a pole x inches per minute how many feet will it rise in y hours ?

Since 1 inch $= \frac{1}{12}$th of a foot,

x inches $= \frac{x}{12}$th of a foot

Hence, in 1 minute the insect creeps up $\frac{x}{12}$th ft ,

in 60 minutes , , , „ $\frac{x}{12} \times 60$ ft

Thus in 1 hour the insect creeps up $5x$ ft

Therefore in y hours it rises $(5x \times y)$ ft

Thus the required number of feet $= 5xy$

Example 3. If a man travels at the rate of x miles per hour, in what time will he finish a journey of 10 miles ?

Since x mile is travelled in 1 hour,

1 mile $\frac{1}{x}$th of an hour

10 miles are , $\frac{10}{x}$ hours

Example 4. The digits of a number beginning from the left are x and y How would you represent the number ?

If the digits be 4 and 5 the number $=10\times4+5$,

if the digits be 5 and 7 the number $=10\times5+7$,

if the digits be 8 and 4 the number $=10\times8+4$

as so on

Hence, it is quite clear that when x and y stand for the digits, the number is to be represented by $10x+y$

EXERCISE 29.

1. The sum of two numbers is 15 if one of the numbers be x what is the other ?

2. The difference of two numbers is 20 if x be the greater what is the other ?

3. The difference of two numbers is 25 if x be the smaller what is the greater ?

4. What is the excess of 25 over y ?

5. What is the defect of $2x$ from y ?

6. If x be one factor of 21 what is the other factor ?

7. What number is less than 100 by $3x$?

8. What number taken from $4x$ gives $3y$ as a remainder ?

9. If a man travels x hours at the rate of y miles an hour how many miles does he travel ?

10. If a man travels at the rate of y miles per hour in what time will he finish a journey of x miles ?

11. A man is x years of age how old will he be 20 years hence ? How old was he 3 years ago ?

12. In x days a man travels 60 miles what is his rate per day ?

13. If a train travels 30 miles in x hours how many feet does it travel in one second ?

14. If I spend x annas a week, how many rupees do I save out of a yearly income of $5x$ rupees ?

15. Write down 5 consecutive numbers of which x is the middle one

16. Write down the sum of 3 consecutive numbers of which the middle one is x

17. What is the odd number next after $2m+1$?

18. What is the even number next before $2x$?

19. If x men take 10 days to do a work, in what time will y men do it?

20. A room is a yards long and b feet wide; what is the measure of the area of the floor in square feet?

21. In the last question find the number of square units in the area when the unit of length is 4 feet?

22. How many miles can a person walk in 20 minutes if he walks x miles in y hours?

23. In what time will a person walk 16 miles, if he walks x miles in a hours?

24. What is the present age of a man who was $(x-5)$ years old 20 years ago? What will be his age 30 years hence?

25. If the digits of a number beginning from the right are x and y, what is the number?

26. If x, y, z be the digits of a number beginning from the left, what is the number?

27. In the preceding question, if the digits be inverted, how would you represent the new number?

66. Easy Problems. We shall now work out some problems which will fairly introduce the beginner to the subject of the present chapter. The unknown quantity will invariably be represented by x.

Example 1. A and B together start a business with a joint-capital of Rs 540. If A's share in the capital be double that of B, find the share of each in the joint-fund.

Let x represent B's share.

Then, A's share in the capital is $2x$.

So the joint-fund $=x+2x$

i.e. $=3x$.

But the joint-fund is Rs 540,

$$3x = \text{Rs } 540,$$

or $$x = \text{Rs } 180,$$

i.e. B's share is Rs 180,

and A's share is Rs 360.

Example 2. Divide 34 into two parts whose difference is 8.

Let x denote the larger part.

Then $34-x$ denotes the smaller part.

Hence by the question

$$x-(34-x)=8,$$

or $$2x-34=8,$$

$\therefore$ $$2x=42 \qquad x=21$$

Thus the larger part is 21 and the smaller part is 13

Example 3. What number is that of which the *third* part exceeds the *fifth* part by 4?

Let x represent the required number

Then, by the given condition,

$$\frac{x}{3}-\frac{x}{5}=4$$

$$5x-3x=60,$$

or $$2x=60 \quad \therefore \quad x=30$$

Example 4. In 10 years A will be twice as old as B was 10 years ago Find their present ages if A is now 9 years older than B

Let the present age of B be denoted by x

Then, the present age of A is $x+9$

After 10 years A's age $=x+\overline{9+10}$,

$=x+19$

Before 10 " B's " $=x-10$

by the given condition,

$$x+19=2(x-10),$$

or, $$x+19=2x-20$$

by transposition $$2x-x=20+19$$

or, $$x=39,$$

i e the present age of $B=39$ years,

" " " " $A=48$ "

EXERCISE 30.

1. A straight line, whose length is 9 feet, is divided into two portions, one being double of the other Find the length of each portion

2. A bag contains as many rupees in it as there are eight-anna pieces Find the number of eight-anna pieces if there be Rs 30 in all

3. Find two numbers whose sum is 50, and whose difference is 30

4. Find a number such that it is equal to five times its defect from 96

5. Find a number which being multiplied by 8, the product will be greater than half the number by 90

6. What number is that from which if you subtract 40, the difference will be one-third of the original number ?

7. What number is that of which the excess over 35 is less by 22 than its defect from 67 ?

8. Four times the excess of a number over 16 is equal to the defect of the number from 416 , find the number

9. Find 3 consecutive numbers whose sum will be 129

10. Find a number which when multiplied by 7 is as much above 132 as it was originally below it

11. Divide 90 into two parts such that three times one of the parts together with four times the other may be equal to 335

12. The sum of two numbers is 39 and *one-fifth* of one of them is equal to *one-eighth* of the other Find them

13. Find a number whose *fourth* part exceeds its *ninth* part by 5

14. Find a number whose *sixth* part exceeds its *eighth* part by 3

15. Divide 21 into two parts, so that ten times one of them may exceed nine times the other by 1

16. A house and a garden cost £850 and the price of the garden=$\frac{5}{12}$ths of the price of the house , find the price of each

17. Divide £120 among two persons, so that for every shilling one receives, the other may receive half a crown

18. Two shepherds, owning a flock of sheep, agree to divide its value *A* takes 72 sheep while *B* takes 92 sheep and pays *A* £35 Find the value of a sheep

19. The ages of two men differ by 10 years, and 15 years ago the elder was just twice as old as the younger , find the ages of the men

20. A father's age is three times that of his son, and in 10 years it will be twice as great , how old are they ?

CHAPTER VII

GRAPHS : PLOTTING OF POINTS

67. Introduction. We have shown in Chapters II and III how certain algebraic ideas and rules may be easily understood by graphical illustrations In fact, graphical representation of anything wherever it is possible, greatly helps to realise the nature of the thing represented In the present chapter we propose to consider how algebraic quantities can be represented by points as a preliminary to geometrical representations of algebraic identities and equations which will be considered later on Such geometrical representations are called **Graphs.**

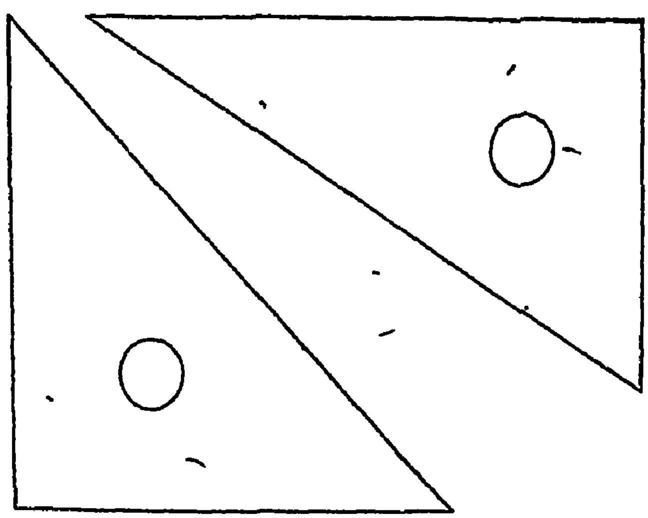
68. Instruments required. The student should first of all provide himself with the following instruments and acquire skill in manipulating them with accuracy and neatness

(*a*) **A hard Pencil.**

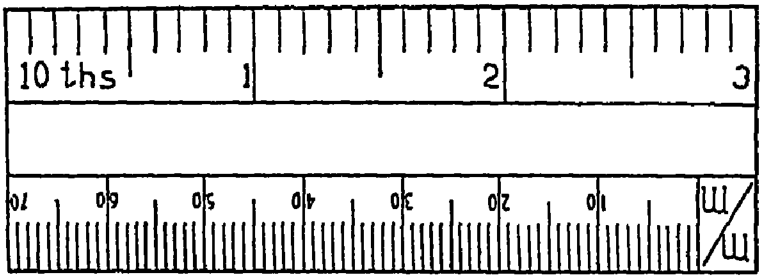
Note *It must be well sharpened so that the lines drawn may be very fine*

(*b*) **A pair of Compasses (also called Dividers).**

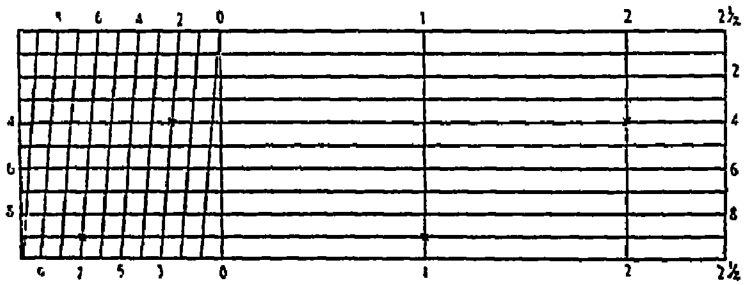
(*c*) **Two Set-squares.**



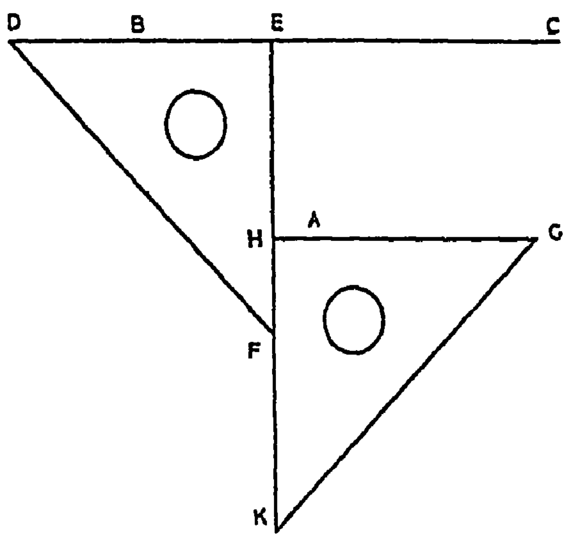
(*d*) **A graduated Flat Ruler** (of moderate length) **shewing tenths of an inch.**



(*e*) **A Diagonal Scale, giving hundredths of an inch.**

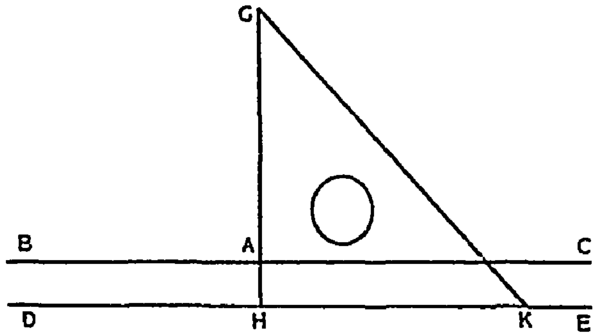


Example 1. Through the point A draw a straight line parallel to BC



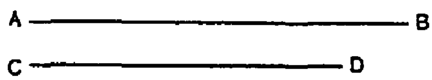
Place the Set-square *DEF* in such a way that the edge *DE* may fall along *BC* Then slip the other Set-square *GHK* into the position shewn in the diagram, so that *HG* may pass by *A* Now trace a line along *HG*, which will evidently be parallel to *BC*

Example 2. Through the point *A* in the straight line *BC* draw a straight line perpendicular on *BC*



First trace a line *DE*, parallel to *BC* Then place the Set-square *GHK* in such a way that *HK* may fall along *DE* and *GH* may pass by *A* Now trace a line along *HG*, which will evidently be perpendicular to *BC*

Example 3. Find the lengths of the straight lines *AB* and *CD*



(1) By means of the Pair of Compasses and the Diagonal Scale we find that the length of *AB* is equal to the distance between the two points marked on the line 4-4 in the diagram Hence the required length = 2·24 **inches.**

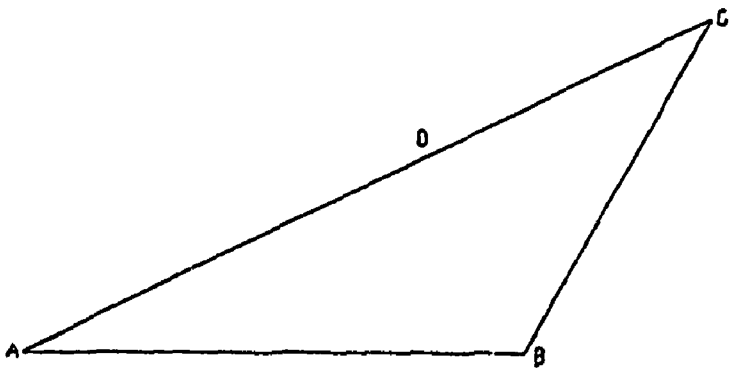
(2) The length of *CD* is found to be equal to the distance between the two points marked on the line 9-9 in the diagram Hence the required length = **1·69 inches.**

EXERCISE 31.

1. Produce the straight line AB to double its length

2. On a given straight line AB a point D is taken supposing it to be the middle point By means of a Pair of Compasses however it is found that AD is a trifle shorter than BD How is the mistake to be corrected ?

3. ABC is a triangle and D is a point on AC as in the following diagram Through D draw towards AB, a straight line parallel to CB



4. In the same diagram, through D draw, away from AB a straight line parallel to BC

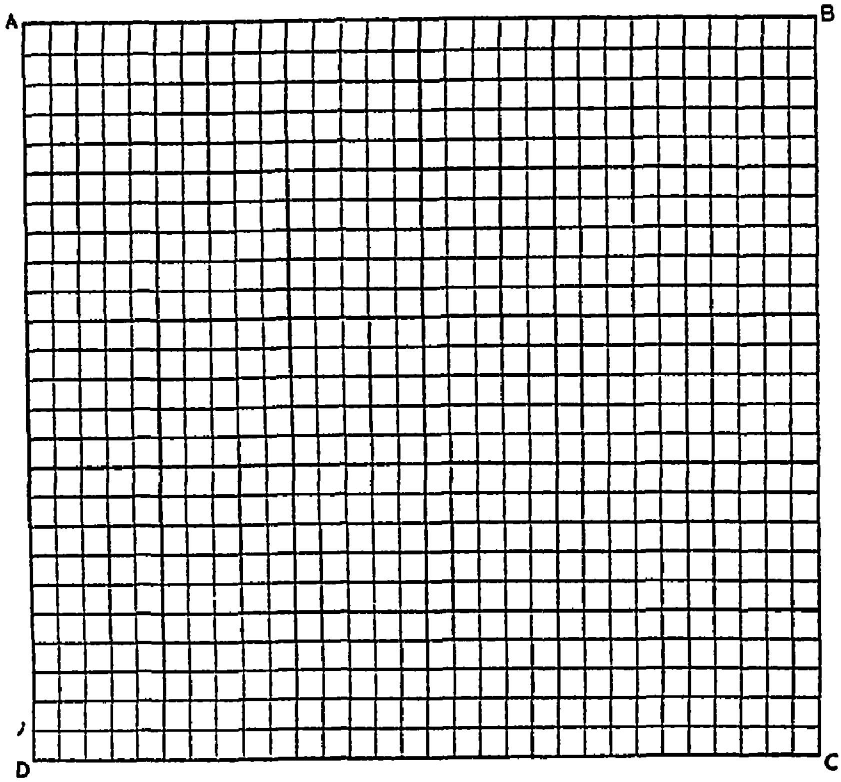
5. In the diagram of example 3 through B draw a straight line parallel to AC

6. From the vertices of a given triangle draw perpendiculars to its opposite sides

7. In example 3, measure the lengths of the sides of the triangle and also measure the lengths of AD and DC

69. Squared Paper. A specimen of a sheet of squared paper is given on the next page

We have two sets of parallel straight lines on the paper One set being parallel to the length, and the other parallel



to the breadth, of the paper, it is clear that every line of the first set is perpendicular to every line of the second The distance between every two consecutive parallels is one-tenth of an inch whilst every two consecutive *thick* parallels are half an inch apart The whole paper is thus divided into a large number of small squares which are equal to one another, each side of each square being one-tenth of an inch in length The paper is also divided into a number of thick-bordered squares, each side of each such square being half an inch in length It is clear also that twenty-five of the small squares are contained in each of the thick-bordered squares

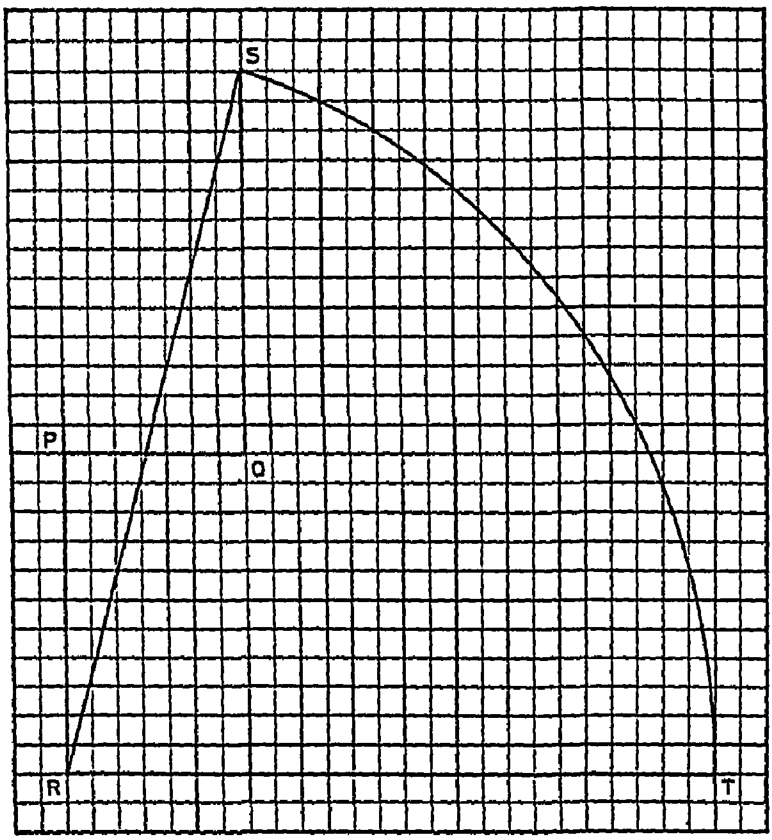
Note 1 *Lines parallel to AB may be regarded as* ***east-and-west*** *lines, and those parallel to AD, as* ***north-and-south*** *lines They may also be considered as* ***horizontal*** *and* ***vertical*** *lines respectively*

Note 2 *For the sake of convenience the length of a side of a small square may be denoted by the symbol a*

Note 3 *The paper may also be ruled so that the length of a side of a small square is only one-tenth of a centimetre (i e a millimetre) instead of one-tenth of an inch In that case the distance between every*

two consecutive thick parallels is evidently half a centimetre or 5 millimetres (One centimetre is approximately equal to 39 of an inch)

Example 1. P, Q, R, S are four stations such that Q is 7 miles east of P, R is 11 miles south of P, and S is 13 miles north of Q Find the distance between R and S



Taking the length of a side of a small square (i e, a) to represent one mile we have P, Q, R, S as in the above figure, where $PQ=7a$, $PR=11a$ and $QS=13a$

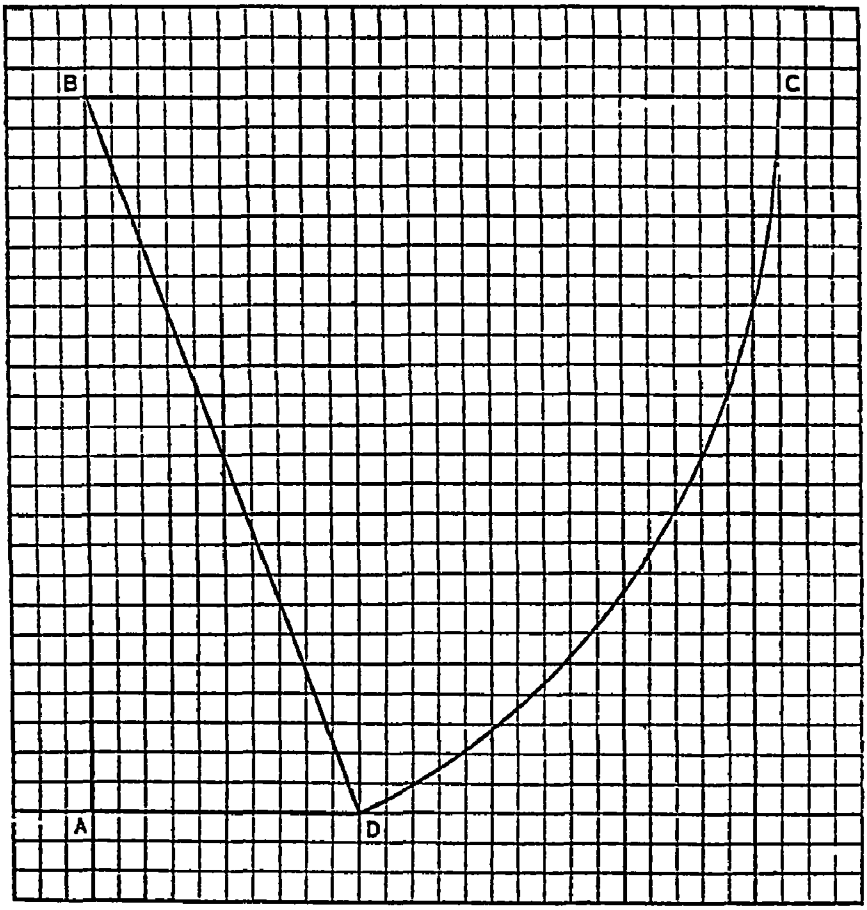
With R as centre and RS as radius describe an arc of a circle cutting the east-and-west line through R at T

Now as $RT=25a$, we have RS also$=25a$ Hence the required distance$=$**25 miles.**

Example 2. An upright post is 8 feet high A string of length 8⅔ feet has one end attached to the top of the post and is held tight with the other end in contact with the ground How far is this end from the foot of the post?

Let $3a$ (i e, 3 times the length of a side of a small square) represent one foot Then 8 feet will be represented by $24a$ and 8⅔ feet by $26a$

Let AB represent the post, so that $AB=24a$ Take a point C on the horizontal line through B such that $BC=26a$



With B as centre and BC as radius describe an arc of a circle cutting the horizontal line through A at D Join BD, then BD represents the string

Now, AD is equal to $10a$, which is $9a+a$ Hence, the required distance $=3\frac{1}{3}$ **feet.**

EXERCISE 32.

1. A is $5\frac{1}{3}$ units of length east of O, and P is 4 units of length north of A How far is P from O?

2. B is 3 feet west of O and Q is $7\frac{1}{5}$ feet south of B How far is Q from O?

3. C is 2 yards north of O and R is $6\frac{6}{7}$ yards west of C How far is R from O?

4. D is 2.1 inches south of O and S is 2.8 inches east of D How far is S from O?

5. A is 27 feet east of O. P is north of A and 45 feet from O. How far is P from A?

6. Q is 24 feet south of B. O is east of B and 25 feet from Q. How far is B from O?

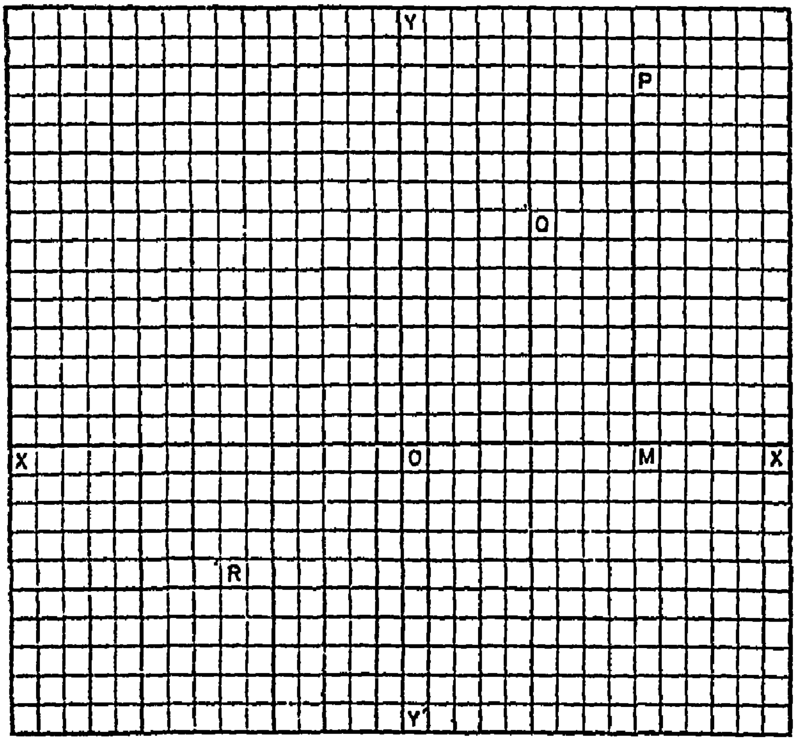
7. B is $4\frac{4}{5}$ yards east of A. C is $\frac{3}{5}$ yard north of A and D is 2 yards north of B. How far is D from C?

8. B is 25 feet north of A. P is 40 feet west of A, and Q is 20 feet east of B. How far is Q from P?

9. Two vertical posts, 14 feet and $3\frac{4}{5}$ feet high, are $13\frac{3}{5}$ feet apart. Find the distance between the tops of the posts.

10. A ladder 30 feet long has its foot at a distance of 10 feet from a vertical wall. How far up the wall does it reach? (The diagonal scale may be used if necessary.)

70. If in a plane, a point and two straight lines passing through it at right angles to each other be given, the position of any point in the plane can be easily defined.



In the plane of the paper as shewn in the last diagram let XOX' and YOY' be the two given straight lines at right

angles to each other If P be any point in the plane, how to know its position ?

We may regard XOX' as the *east-and-west* line, and YOY' as the *north-and-south* line Draw PM parallel to YOY' meeting XOX' at M Evidently then M is due east of O, and P due north of M Hence if OM and MP be known we know the position of P at once

Taking the length of a side of a small square as the unit of length, we have $OM=9$ units of length and $MP=12$ units of length Hence, the position of P may be briefly defined as follows

9 units east, 12 units north

Note 1 *If Q be a point whose position is defined to be 5 units east, 8 units north, to find Q all that we have to do is to take a point 5 units due east of O and thence proceed 8 units northwards*

Note 2 *If R be a point whose position is defined to be 7 units west, 4 units south, to find R all that we have to do is to take a point 7 units due west of O and thence proceed 4 units southwards*

EXERCISE 33.

[*Squared Paper is to be used in every case*]

1. Find the points whose positions are defined as follows ·

(1) 5 units east, 7 units north

(2) 8 units west, 5 units north

(3) 10 units west, 12 units south

(4) 15 units east, 6 units south

(5) 8 units west, 13 units north

(6) 14 units east, 15 units south

2. It is clear from Chapter II (Positive and Negative Quantities) that "6 units west" is the same as "-6 units east," and "8 units south" is the same as "-8 units north" Hence find the points whose positions are defined as follows

(1) 7 units east, -8 units north

(2) -10 units east, 6 units north

(3) -9 units east -13 units north

3. In defining the position of a point the words "east" and "north" may be omitted if it is accepted as a rule that the distance measured towards the east should invariably be mentioned first On this convention find the points whose positions are defined as follows

(1) 8 units, 9 units (2) 6 units -11 units

(3) -12 units, 15 units (4) -10 units, -14 units

4. We may define the position of a point still more briefly if the word 'units" be omitted Find, then, the points whose positions are defined as follows

(1) 6, 4 (2) 13 8 (3) -7, 6

(4) 8 -6 (5) -10, -13 (6) -9, -15

71. Definitions. The student is referred to the diagram of the last article The given lines XOX' and YOY' with reference to which the positions of all points in the plane are defined, are called the **axes of co-ordinates ;** and the point O, where these lines intersect, is called the **origin.**

The straight line XOX' is called the **axis of x** and the straight line YOY' the **axis of y.**

The lengths OM and MP which define the position of the point P are called its **co-ordinates,** OM being called the **abscissa** (or **x-co-ordinate)** and MP, the **ordinate** **(or y-co-ordinate).**

'The point (x, y)' or simply "(x, y)" means "the point whose abscissa$=x$ units of length and ordinate$=y$ units of length'

Note 1 *When we speak of the "x and y" of a point, we mean its abscissa and ordinate*

Note 2 *The abscissa is positive or negative according as M is the right or on the left of O The ordinate is positive or negative according as P is above or below XOX'*

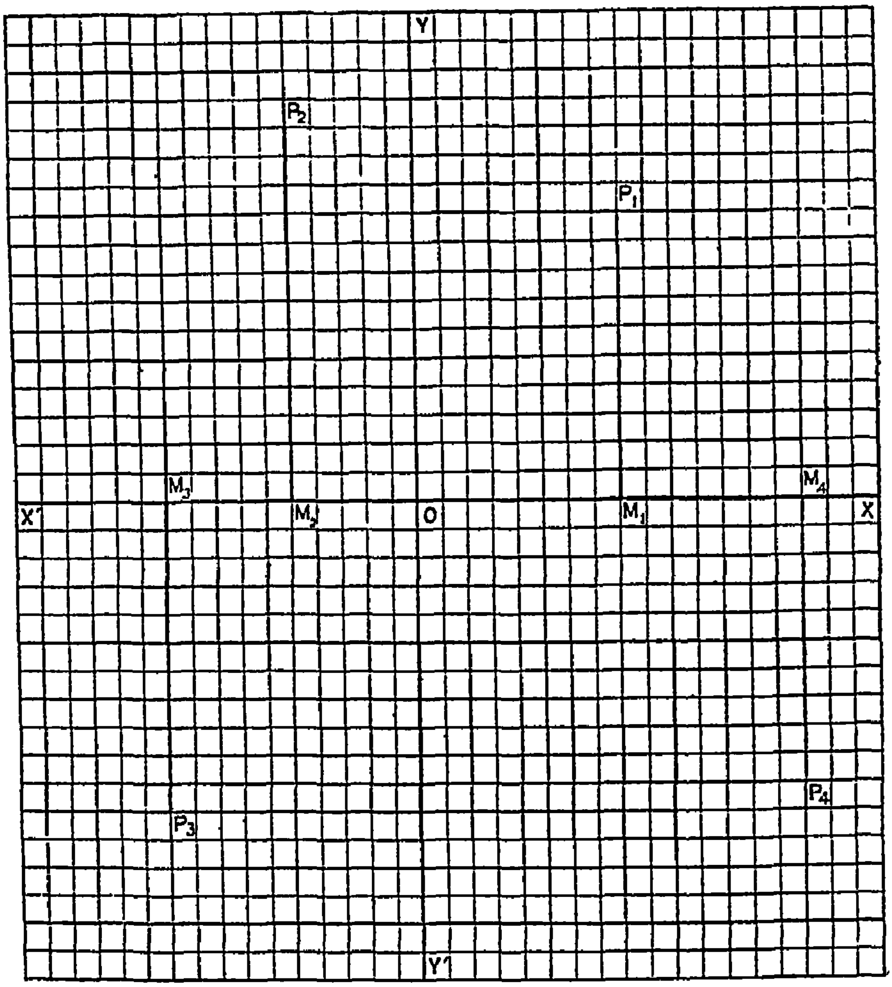
Note 3 ***"To plot a point"*** *is to find the position of a point when its co-ordinates are given*

Example 1. In the diagram given on the next page, write down the co-ordinates of the points P_1 P_2, P_3, P_4

The figure explains itself Take the length of a side of a small square as the unit of length

(1) $OM_1=8$ units and M_1 is on the *right* of O. $M_1P_1=10$ units and P_1 is *above* the line XOX' Hence the co-ordinates of P_1 are **8** and **10.**

(2) $OM_2=5$ units and M_2 is on the *left* of O, $M_2P_2=13$ units and P_2 is *above* the line XOX' Hence the co-ordinates of P_2 are **−5** and **13.**

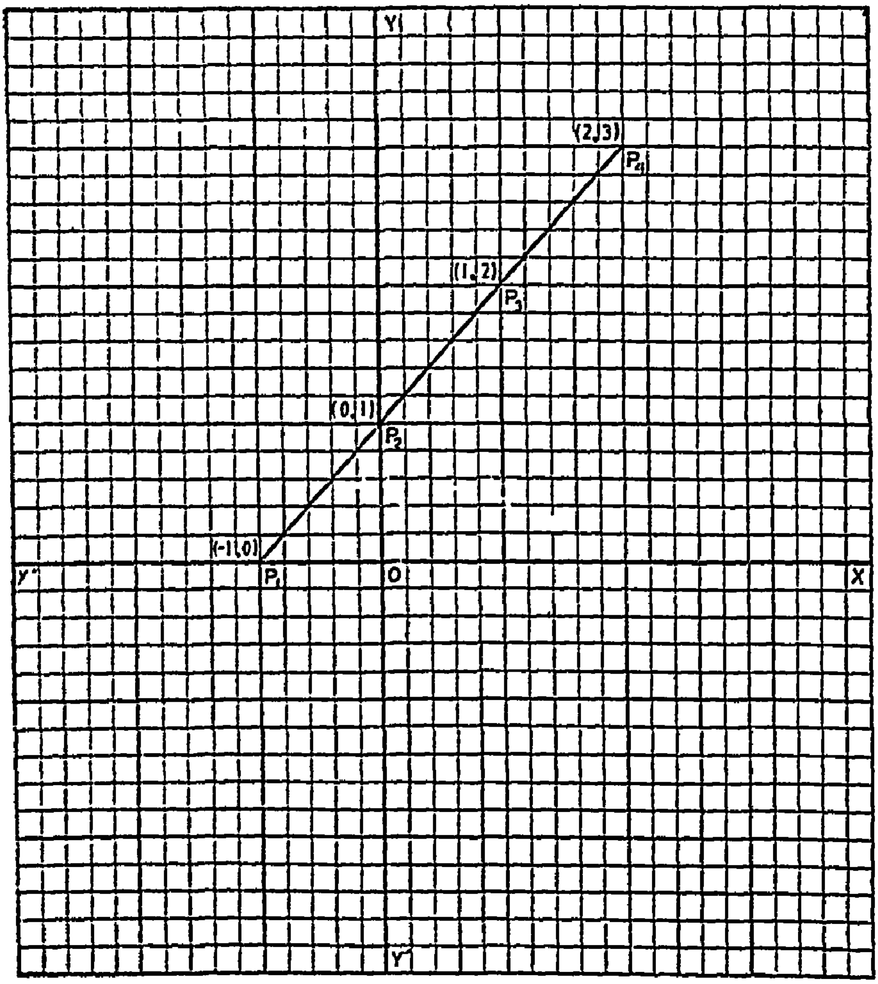


(3) $OM_3=10$ units and M_3 is on the *left* of O, $M_3P_3=11$ units and P_3 is *below* the line XOX'. Hence the co-ordinates of P_3 are **−10** and **−11.**

(4) $OM_4=15$ units and M_4 is on the *right* of O, $M_4P_4=10$ units and P_4 is *below* the line XOX' Hence the co-ordinates of P_4 are **15** and **−10.**

Example 2. Plot the points $(-1, 0)$, $(0, 1)$, $(1, 2)$ and $(2, 3)$, and show that they all lie in a straight line

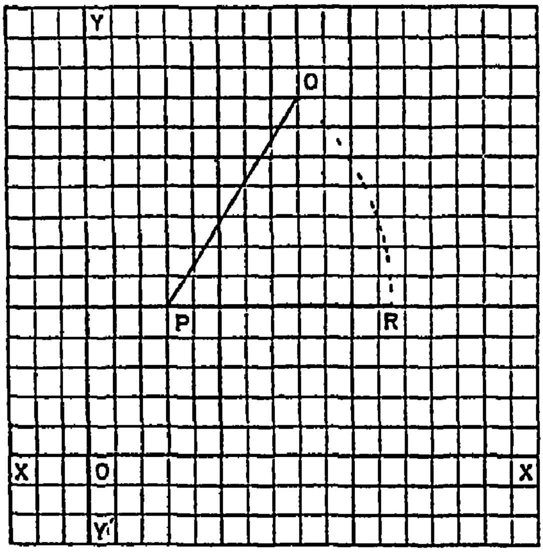
Let 5 times the side of a small square represent the unit of length and let P_1 P_2, P_3 P_4 respectively denote the four given points Then the positions of the points will be as shown in the figure



Now we find that a Flat Ruler may be so placed that its edge will pass through all the four points Hence they all lie in the same straight line

Example 3. Plot the points $(3, 5)$ and $(8, 12)$ and find the distance between them

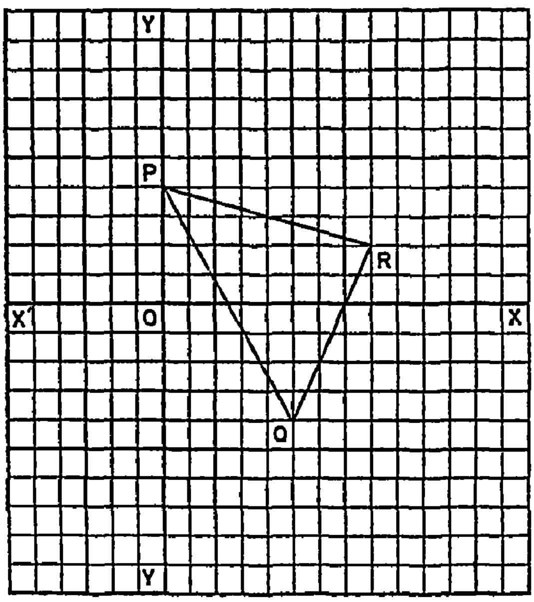
Let a side of a small square represent the unit of length, and let P and Q respectively denote the two given points Then the positions of the points will be as shewn in the figure



With centre P and radius PQ draw a circle cutting the east-west line through P at R

The distance required $= PQ = PR = 8\ 6$ units [from the figure]

Example 4. Plot the points $P(0, 4)$, $Q(5\ -4)$ and $R(8, 2)$ and find the area of the triangle PQR

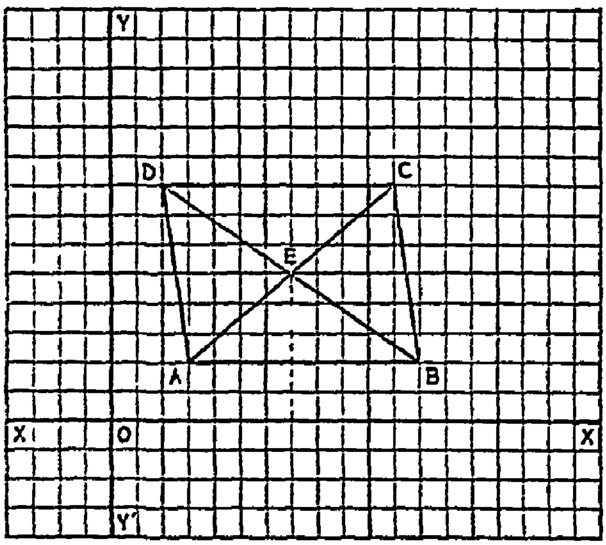


Let a side of a small square be the unit of length. Then the positions of the points P, Q R will be as shewn in the diagram Count the number of small squares falling *wholly* inside the triangle PQR Of the remaining squares through which the sides pass, find the number of *only* those *half* or *more than half* of which are within the triangle and reject the others Since each small square represents a unit of area the total number of small squares thus counted will give the area of the triangle pretty accurately

• Counting by the above method the number of small squares in the triangle $PQR = 27$

Hence the required area $= 27$ units of area

Example 5. Plot the points $A(3, 2)$ $B(12, 2)$, $C(11, 8)$ and $D(2\ 8)$ Find the area of the quadrilateral $ABCD$ and read the co-ordinates of the intersection of AC and BD



Take a side of a small square as the unit of length Then the positions of the points A B C and D will be as shown in the diagram

Counting by the method of example 3, the number of small squares in the quadrilateral $ABCD = 54$

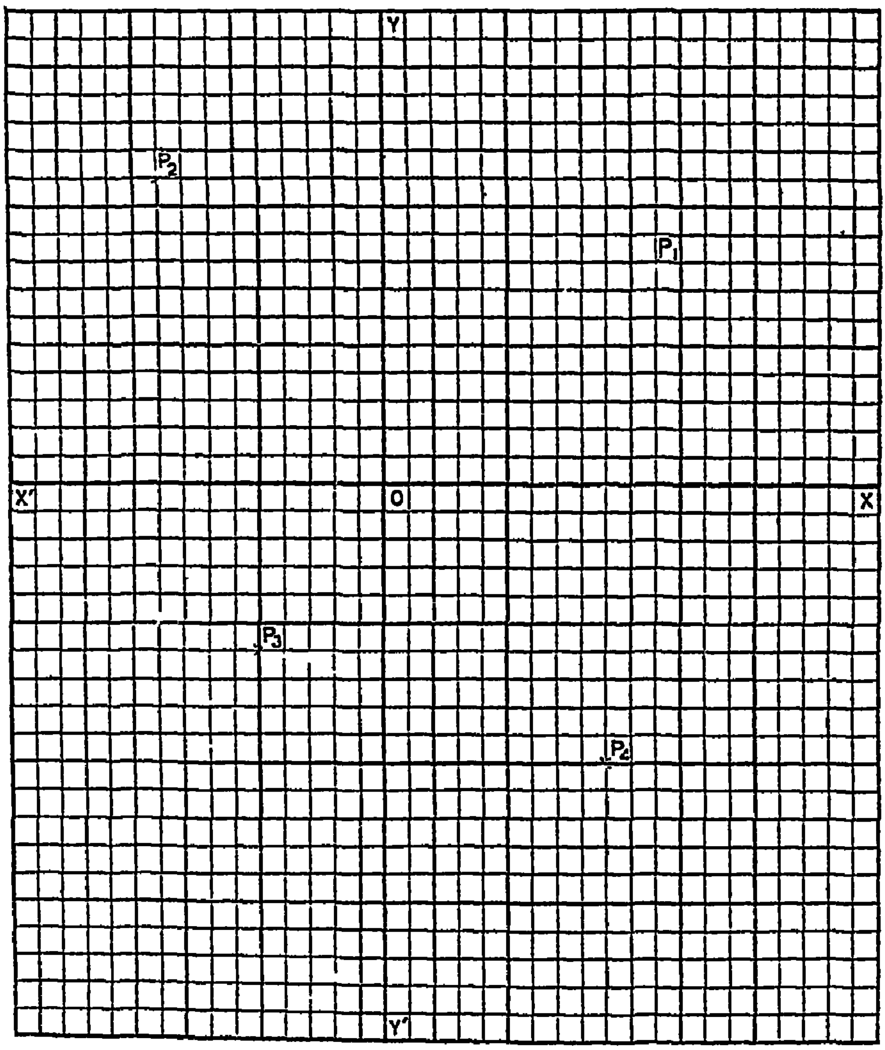
Hence the area required $= 54$ units of area

Also for the diagram the co-ordinates of E the intersection of AC and BD are 7 and 5

EXERCISE 34.

1. In the diagram given below, what are the co-ordinates of the points P_1, P_2, P_3, P_4, (i) when the unit of length is represented by a side of a small square, (ii) when the unit of length is represented by 5 times the side of a small square?

2. In the following diagram what will be the co-ordinates of the points if the unit of length be represented by three times the side of a small square?



3. Plot the points $(-4,-4)$, $(7, 7)$, $(13, 13)$, and satisfy yourself that they lie in a straight line passing through the origin.

4. Plot the points $(-8, 4)$ and $(10, -5)$, and satisfy yourself that the straight line joining them passes through the origin

5. Plot the points $(8, 5)$ and $(-4, -11)$, and find the distance between them

6. Plot the points $(-7\ 9)$ and $(-12, 21)$ and find the distance between them

7. Plot the points $(-11\ 13)$ and $(3\ -35)$, and find the distance between them

8. Join the points $(0, 0)$ and $(5, 5)$, and produce the straight line both ways Find the ordinate of the point on this straight line whose abscissa is 11 and the abscissa of the point whose ordinate is -13

9. Join the points $(0, 7)$ and $(12, 0)$, and produce the straight line both ways Find the ordinate of the point on the straight line whose abscissa is -18 and the abscissa of the point whose ordinate is -14

10. Join the points $(-4, 0)$ and $(0, -8)$, and produce the straight line both ways Find the ordinate of the point on the straight line whose abscissa is -10 and the abscissa of the point whose ordinate is -24

11. Plot the points $A(3, 2)$, $B(3, 7)$ and $C(8, 5)$, and find the area of the triangle ABC

12. Plot the points $P(-2, 5)$, $Q(6. 5)$ and $R(8, 9)$, and find the area of the triangle ABC

13. Plot the points $D(5, 2)$, $E(6, 8)$ and $F(7, 12)$, and find the area of the triangle DEF

14. Find the area of the quadrilateral whose vertices are $(11, 2)$, $(3, 2)$, $(3\ 7)$ and $(11, 7)$ Obtain the co-ordinates of the intersection of its diagonals

15. Find the area of the quadrilateral whose vertices are (i) $(16, 6)$, $(2, 3)$ $(11, 14)$ and $(5, 11)$, (ii) $(3, 6)$, $(5, 4)$, $(17, 16)$ and $(9\ 18)$, (iii) $(-12, 5)$, $(-12, -10)$, $(16, -10)$ and $(16, 5)$, (iv) $(0, 1)$, $(10, 8)$, $(2\ 13)$ and $(-2, 8)$

16. Construct a triangle whose base is 12 centimetres and the two other sides are 5 and 13 centimetres respectively Find the area of the triangle, the altitude and the angle opposite to the longest side

17. Construct a triangle whose base is 6 centimetres and the two other sides are 3 and 5 centimetres respectively Measures the altitude as accurately as possible

18. Plot the following series of points

(i) (6, 0), (6, 3), (6, 4), (6, 6), (6, 8) and (6, 10)

(ii) (−2, 7), (3, 7) (5 7), (7, 7), (8, 7) and (10, 7)

Show that they lie on two straight lines respectively parallel to the axis of y and the axis of x Find the co-ordinates of their point of intersection

19. Plot the points (3 4), (4, 3), (5, 0), (−4, −3), (4, −3) Find their distances from the origin and show that they lie on a circle with the origin as centre

20. Plot the points $A(5, 2)$, $B(9, 2)$, $C(5, 8)$, $D(9, 8)$ and $E(7, 12)$ Find the area of the figure $ABDEC$ and the co-ordinates of the intersection of AD and BC

Miscellaneous Exercises. II

I

1. From the identity $(a+b)^2=a^2+2ab+b^2$, deduce the square of $x-y-z$ by putting x for a and $-y-z$ for b

2. Establish the following formulæ

(i) $a^2+b^2=\frac{1}{2}\{(a+b)^2+(a-b)^2\}$

(ii) $4ab=(a+b)^2-(a-b)^2$

3. Prove that

$$(y-z)(y+z-x)+(z-x)(z+x-y)+(x-y)(x+y-z)=0$$

4. Prove that

$$(a-b)(a+1)(b+1)-a(b+1)^2+b(a+1)^2=(a-b)(a+b+2ab)$$

5. If $a=x+m$, $b=y+m$, $c=z+m$, show that

$$a^2+b^2+c^2-bc-ca-ab=x^2+y^2+z^2-yz-zx-xy$$

6. If $s=a+b+c$ prove that

$$(as+bc)(bs+ac)(cs+ab)=(b+c)^2(c+a)^2(a+b)^2$$

7. Divide $(m+n)^3-27p^3$ by $m+n-3p$

8. Find the quotient when the dividend is $(9x^2-17xy+13y^2)^2$ the remainder is $49y^2(2x+5y)^2$ and the divisor is $3x^2-xy+16y^2$

9. If $x+\frac{2}{y}=\frac{8}{3}$ and $y+\frac{3}{x}=\frac{9}{2}$, find the value of

$$x^3y^3+\frac{216}{x^3y^3}.$$

10. Show that

$$(x-y+z)^3+(x+y-z)^3+6x(x-y+z)(x+y-z)=8x^3$$

II

Solve the following equations

1. $3(x-3)-2(x-2)+x-1=x+3+2(x+2)+3(x+1)$

2. $(x-3)(x-5)=(x-2)(x-7)$

3. $2(x+1)(x+3)+8=(2x+1)(x+5)$

Find the value of x, when

4. $(a+b)(b-x)=b(a-x)$

5. $\frac{mnx-p}{mn}+\frac{npx-m}{np}+\frac{pmx-n}{pm}=\frac{2p}{mn}+\frac{2m}{np}+\frac{2n}{pm}$

6. $\frac{2x+7}{7}-\frac{9x-8}{11}=\frac{x-11}{2}$. **7.** $4x-\frac{x-1}{2}=x+\frac{2x-2}{5}+24.$

8. $x-\frac{x-2}{2}=5\frac{3}{4}-\frac{x+10}{5}+\frac{x-2}{4}.$

9. $\frac{2x-1}{2}+\frac{3x-2}{3}+\frac{4x-3}{4}=\frac{1}{12}.$

10. $\frac{2}{3}(x-1)-\frac{5}{8}(2x-3)+\frac{3}{4}(1-2x)=\frac{1}{12}(4x-5)$

III

1. Find the number to which, if 29 be added the sum will exceed four times the number by 8

2. Find a number whose 7th part exceeds the 9th part by 4

3. A man saves one-tenth of his monthly income and spends one-third of the remainder in buying petty things At the end of the month, he has Rs 300 in his pocket after meeting all the current expenses which amounted to two-fifths of the total income Find his income per month

4. A merchant invests two-fifths of his capital in sugar business one-third in jute and half of the remainder in cloth and has £300 cash Find his capital and the money invested in each business

5. A is twice as old as B and four years older than C The sum of the ages of A, B and C is 96 years Find the age of each.

6. Two sums of money are together equal to £54 12s and there are as many pounds in the one as there are shillings in the other Find the sums

7. Plot the following points on a squared paper and verify that they are the angular points of a rectangle Show that the length of each of the diagonals is 5

$$(1\tfrac{1}{2}, 2), (-1\tfrac{1}{2}, 2), (-1\tfrac{1}{2}, -2) \text{ and } (1\tfrac{1}{2}, -2)$$

8. O is a fixed station A is 20 miles north of O B is 4 miles east of A C is 17 miles south of B Show that the distance between O and C is 5 miles

9. If, in the above example, A be 12 miles west of O and P be 5 miles north of A, and B be 12 miles east of O and Q be 5 miles south of B, show that the distance between P and Q is 26 miles

10. Plot the following points on a squared paper and verify that they lie on a straight line through the origin $(-5, -10)$, $(1, 2)$ and $(3, 6)$

CHAPTER VIII

HARDER ADDITION AND SUBTRACTION

I. Addition.

72. In Chapter III, we have explained the following laws of addition of algebraic quantities and expressions

(1) If any number of quantities are added together, the result will be the same in whatever order the quantities may be taken Thus,

$$a+b+c=b+c+a=c+a+b, \text{ etc} \qquad \text{[Art 31]}$$

This is called the **Commutative Law** of Addition

(2) When any number of quantities are added together they can be divided into groups and the result expressed as the sum of those groups Thus,

$$a+b+c=a+(b+c)=(a+b)+c=b+(c+a), \text{ etc} \qquad \text{[Art 32]}$$

This is called the **Associative Law** of Addition

(3) When any number of *like terms with numerical co-efficients* are added, their sum is a *like term* whose co-efficient is equal to the sum of the co-efficients of the terms added [Art 32]

Thus, the sum of $5x$ $-2x$ $7x$ $6x$ is $16x$ since $5+(-2)+7+6=16$

This process is known as *collecting terms*

The ordinary rule for adding together compound expressions with like and unlike terms has also been explained in Art 33

We have so far applied these rules to simple cases and now propose to consider more difficult problems

73. Compound expressions with fractional co-efficients. If compound expressions with fractional co-efficients are to be added first simplify each expression if necessary and then put the expressions under one another so that like terms stand in the same vertical column, and draw a line below the last expression then add up each vertical column and put the result below it Simplify the co-efficients in the result by Arithmetical Rules

The following examples will illustrate the process

Example 1. Add together

$$\frac{x}{3}+\frac{y}{5}-\frac{z}{7},\ -\frac{9}{10}y+\frac{12}{7}z+\frac{7}{3}x+12a \text{ and } \frac{3}{7}z-\frac{2}{3}x+\frac{4}{5}y-2b$$

$$\begin{aligned}
\text{The 1st expression} &= \tfrac{1}{3}x+\tfrac{1}{5}y-\tfrac{1}{7}z \\
\text{The 2nd expression} &= \tfrac{7}{3}x-\tfrac{9}{10}y+\tfrac{12}{7}z+12a \\
\text{The 3rd expression} &= -\tfrac{2}{3}x+\tfrac{4}{5}y+\tfrac{3}{7}z\qquad -2b \\
\hline
\text{The sum} &= 2x+\tfrac{1}{10}y+2z+12a-2b
\end{aligned}$$

[In the sum

the co-efficient of $x=\frac{1}{3}+\frac{7}{3}-\frac{2}{3}=\frac{1+7-2}{3}=\frac{6}{3}=2,$

the co-efficient of $y=\frac{1}{5}-\frac{9}{10}+\frac{4}{5}=\frac{2-9+8}{10}=\frac{10-9}{10}=\frac{1}{10}.$

the co-efficient of $z=-\frac{1}{7}+\frac{12}{7}+\frac{3}{7}=\frac{-1+12+3}{7}=\frac{14}{7}=2$

the co-efficient of $a=0+12+0=12$

the co-efficient of $b=0+0-2=-2$]

Note *Notice that places of like terms in 'a' are vacant in the 1st and 3rd expressions For convenience, the co-efficients of 'a' in these places may be taken to be zero Similarly, the co-efficients of the like terms in b may be taken as zero in the 1st and 2nd expressions.*

Example 2. Find the sum of $\frac{6x-2y}{6}+\frac{4y-3z}{12}+\frac{2z-4x}{8}$, $\frac{4x-3y}{12}+\frac{6y-4z}{8}+\frac{3z-6x}{6}$ and $\frac{2x-4y}{8}+\frac{3y-2z}{6}+\frac{4z-6x}{12}$.

Simplifying each of the expressions by collecting terms and proceeding as above, the sum follows Thus,

The 1st exp $=(\frac{6}{6}-\frac{4}{8})\,x+(-\frac{2}{6}+\frac{4}{12})y+(-\frac{3}{12}+\frac{2}{8})z$

$=(1-\frac{1}{2})\,x+(-\frac{1}{3}+\frac{1}{3})\,y+(-\frac{1}{4}+\frac{1}{4})z=\ \frac{1}{2}x$

The 2nd exp $=(\frac{4}{12}-\frac{6}{6})\,x+(-\frac{3}{12}+\frac{6}{8})\,y+(-\frac{4}{8}+\frac{3}{6})z$

$=(\frac{1}{3}-1)\,x+(-\frac{1}{4}+\frac{3}{4})\,y+(-\frac{1}{2}+\frac{1}{2})z=-\frac{2}{3}x+\frac{1}{2}y$

The 3rd exp $=(\frac{2}{8}-\frac{6}{12})x+(-\frac{4}{8}+\frac{3}{6})\,y+(-\frac{2}{6}+\frac{4}{12})z$

$=(\frac{1}{4}-\frac{1}{2})\,x+(-\frac{1}{2}+\frac{1}{2})\,y+(-\frac{1}{3}+\frac{1}{3})z=-\frac{1}{4}x$

$\therefore$ The sum $=-\frac{5}{12}x+\frac{1}{2}y$

[In the sum,

the co-efficient of $x=\frac{1}{2}-\frac{2}{3}-\frac{1}{4}=\frac{6-8-3}{12}=\frac{-5}{12}$,

the co-efficient of $y=0+\frac{1}{2}+0=\frac{1}{2}$]

Example 3. Find the numerical value of the sum of

$$\frac{3}{7}x^3+\frac{5}{11}y^5-20a^2+\frac{49}{2}b^3, \qquad 17a^2-\frac{27}{2}b^3-\frac{23}{7}x^3,$$

$$-\frac{y^5}{11}+\frac{3}{2}b^3-3a^2 \quad \text{and} \quad -\frac{23}{2}b^3-\frac{4}{11}y^5+7a^2+\frac{20}{7}x^3,$$

when $x=98$, $y=79$, $a=5$ and $b=4$

In this problem, the numerical value can be obtained easily from the sum of the expressions,

The 1st expression $=\ \frac{3}{7}x^3+\frac{5}{11}y^5-20a^2+\frac{49}{2}b^3$

The 2nd expression $=-\frac{23}{7}x^3\qquad +17a^2-\frac{27}{2}b^3$

The 3rd expression $=\qquad -\frac{1}{11}y^5-\ 3a^2+\ \frac{3}{2}b^3$

The 4th expression $=\ \frac{20}{7}x^3-\frac{4}{11}y^5+\ 7a^2-\frac{23}{2}b^3$

The sum $=\qquad a^2+\ b^3$

$=5^2+4^3=5\times5+4\times4\times4=25+64=89$

[In the result,

the co-efficient of $x = \frac{3}{7} - \frac{23}{7} + 0 + \frac{20}{7} = \frac{3-23+0+20}{7} = \frac{0}{7} = 0$,

the co-efficient of $y = \frac{5}{11} + 0 - \frac{1}{11} - \frac{4}{11} = \frac{5+0-1-4}{11} = \frac{0}{11} = 0$.

the co-efficient of $a^2 = -20+17-3+7 = 24-23 = 1$,

the co-efficient of $b^3 = \frac{49}{2} - \frac{27}{2} + \frac{3}{2} - \frac{23}{2} = \frac{49-27+3-23}{2}$

$= \frac{52-50}{2} = \frac{2}{2} = 1$]

74. Compound expressions with literal co-efficients Co-efficients which are not wholly numerical are called literal Thus, the co-efficients of x in ax, $6bx$ $(c+d-e)x$, being a, $6b$, $(c+d-e)$, respectively are literal

The terms ax, $6bx$, $(c+d-e)x$, if considered in respect of x, differ in their literal co-efficients only and are also called *like* when thus considered

If ax and bx be two like terms in x,

their sum $= ax + bx = (a+b)x$

Hence, the sum of two like terms is a like term whose co-efficient is *the sum of the co-efficients of the two terms* By Art 47, Cor 3, this rule for addition will be true even when the number of terms is greater than two

Thus, the rule for addition of like terms is same for all co-efficients numerical as well as literal

It, therefore, follows that the rule for adding compound expressions is same for both of these co-efficients

The following examples will illustrate the above rule

Example 1. Add together

$(b+c)x+(c+a)y+(a+b)z$, $ax+by+cz$ and $x+y+z$

Arranging the expressions so that like terms may stand in the same vertical column and adding up each such column, the sum follows Thus,

The 1st exp $= (b+c)x + (c+a)y + (a+b)z$

The 2nd exp $= ax \quad + by \quad + cz$

The 3rd exp $= \; x \quad + \; y \quad + \; z$

$\therefore$ The sum $= (a+b+c+1)x + (a+b+c+1)y + (a+b+c+1)z$

[In the result,

the co-efficient of $x = (b+c)+a+1 = a+b+c+1$,

the co-efficient of $y = (c+a)+b+1 = a+b+c+1$,

the co-efficient of $z = (a+b)+c+1 = a+b+c+1$]

Example 2. Add together: $(b-c)x+(c-a)y+(a-b)z$, $(b-c)y+(a-b)x+(c-a)z$ and $(b-c)z+(c-a)x+(a-b)y$

The expressions contain like terms in respect of x, y and z. Hence, arranging like terms in the same vertical column and proceeding as before, the result follows. Thus

$$\begin{array}{ll}
\text{The 1st expression} & =(b-c)x+(c-a)y+(a-b)z \\
\text{The 2nd expression} & =(a-b)x+(b-c)y+(c-a)z \\
\text{The 3rd expression} & =\underline{(c-a)x+(a-b)y+(b-c)z} \\
\therefore\ \text{The sum} & =0
\end{array}$$

[In the sum,

the co-efficient of $x=(b-c)+(c-a)+(a-b)$
$=b-c+c-a+a-b=0$

Similarly, the co-efficients of y and z are zero.]

Example 3. Find the sum of $(ax-by)+(bx-cz)$, $(ay-bx)+(by-cz)$ and $(cz-ax)+(cz-by)$.

Each of these three expressions contain like terms in respect of x, y and z. Arranging each expression in terms of x, y and z and proceeding as in previous examples the sum is obtained. Thus

$$\begin{array}{llrrr}
\text{The 1st exp} = & ax+bx-by-cz= & (a+b)x- & by- & cz \\
\text{The 2nd exp} = & -bx+ay+by-cz= & -bx & +(a+b)y- & cz \\
\text{The 3rd exp} = & -ax-by+2cz\quad = & -ax- & by+ & 2cz \\
\hline
 & \therefore\ \text{The sum}= & & (a-b)y &
\end{array}$$

[In the sum,

the co-efficient of $x=\ (a+b)-b-a=\ a+b-b-a=0$

the co-efficient of $y=-b+(a+b)-b=-b+a+b-b=a-b$

the co-efficient of $z=-c-c+2c=0$.]

Note 1. *When compound expressions with brackets are to be added to like compound expressions it is more convenient to retain brackets as in Example 2.*

Note 2. *The expressions to be added should be simplified by **collecting terms** if necessary as in Example 3.*

Example 4. Find the sum of

$(a^2+b^2)x+(b^2+c^2)y+(c^2+a^2)z$, $(b^2+c^2)m+(c^2+a^2)n$, $(c^2+a^2)p+(a^2+b^2)q$ and $(a^2+b^2)j+(b^2+c^2)k$

The expressions contain like terms in respect of (b^2+c^2) (c^2+a^2) and (a^2+b^2) Hence, arranging like terms in the same vertical column and proceeding as before,

$$\begin{array}{ll}
\text{1st expression}= & x(a^2+b^2)+y(b^2+c^2)+z(c^2+a^2) \\
\text{2nd expression}= & \qquad\qquad\quad\; m(b^2+c^2)+n(c^2+a^2) \\
\text{3rd expression}= & q(a^2+b^2) \qquad\qquad\quad\;\; +p(c^2+a^2) \\
\text{4th expression}= & j(a^2+b^2)+k(b^2+c^2) \\
\hline
\end{array}$$

the sum

$$=(x+q+j)(a^2+b^2)+(y+m+k)(b^2+c^2)+(z+n+p)(c^2+a^2)$$

[In the result,

the co-efficient of $(a^2+b^2)=x+0+q+j=x+q+j$

Similarly, the co-efficients of (b^2+c^2) and (c^2+a^2) are $(y+m+k)$ and $(z+n+p)$ respectively

EXERCISE 35.

Add together

1. $2x^2-5xy+y^2$ $4y^2-7x^2-5x+2y$ $3xy-5+y-6y^2$ and $3-4y+3x$

2. $abc+a^2b-b^2c^2$ $5a^2b-12b^2c^2-3abc$ $8b^2c^2-4a^2b+2abc$ and $2a^2b+5b^2c^2$

3. $m^3n^2-3mnp+2m^2n^3+6m^2n^2$, $7mnp-10m^2n^2+5m^3n^2-m^2n^3$, $2m^2n^2-5mnp+3m^2n^3$ and $-7m^3n^2+m^2n^2-4m^2n^3$

4. $12a^3b^2x-29b^3x^2a+37x^3a^2b+45a^2b^2x^2$, $25b^3x^2a-16a^2b^2x^2-18a^3b^2x-5x^3a^2b$, $32a^2b^2x^2-23x^3a^2b+20a^3b^2x-28b^3x^2a$ and $-9x^3a^2b-14a^3b^2x-60a^2b^2x^2+32b^3x^2a$

5. $-15a^4b^4c^4+7c^4a^3b^5-24b^4c^3a^5+27a^4b^3c^5$ $19c^4a^3b^5-15a^4b^3c^5+23a^4b^4c^4-8b^4c^3a^5$, $29b^4c^3a^5+11a^4b^4c^4-9a^4b^3c^5-16c^4a^3b^5$ and $-3a^4b^3c^5-10c^4a^3b^5+3b^4c^3a^5-18a^4b^4c^4$

6. $25a^3b^3-8b^3c^3-23c^3a^3+19a^2b^2c^2$ $16c^3a^3-14a^2b^2c^2-19a^3b^3-12b^3c^3$, $27a^2b^2c^2+13a^3b^3+17c^3a^3-20b^3c^3$, $29b^3c^3-6a^2b^2c^2-21a^3b^3-13c^3a^3$ and $10b^3c^3+3a^3b^3+4c^3a^3-27a^2b^2c^2$

7. $5a^3-18b^3-50c^3-25abc$ $38c^3-37a^3-7abc+29b^3$, $26abc-17c^3+11b^3+43a^3$ $13b^3-18abc+4a^3+21c^3$ and $-14a^3+12c^3+21abc-34b^3$

8. $\frac{x}{2}+\frac{y}{3}+\frac{z}{5}$, $\frac{3x}{4}+\frac{y}{3}+\frac{3z}{5}$ and $\frac{3x}{4}+y+\frac{6z}{5}$.

9. $\frac{3x}{5}+\frac{4y}{7}+\frac{10z}{11}$, $\frac{2y}{7}+\frac{4z}{11}+\frac{x}{5}$ and $\frac{8z}{11}+\frac{6x}{5}+\frac{8y}{7}$.

10. $\frac{4x^2y}{15}+\frac{4y^2z}{13}+\frac{5z^2x}{17}$, $\frac{7y^2z}{13}+\frac{6z^2x}{17}+\frac{7x^2y}{15}$ and $\frac{6z^2x}{17}+\frac{4x^2y}{15}+\frac{2y^2z}{13}$.

11. $\frac{7a^2b}{19}+\frac{9b^2c}{17}+\frac{11ca^2}{21}+\frac{13ab^2}{35}$, $\frac{8b^2c}{17}+\frac{10c^2a}{21}+\frac{12a^2b}{19}+\frac{17bc^2}{35}$ and $\frac{22ab^2}{35}+\frac{18bc^2}{35}+\frac{10ca^2}{21}+\frac{11ac^2}{21}$.

12. $\frac{2abc^2}{3}+\frac{3}{4}\,bca^2+\frac{4}{7}b^2d$ $\frac{5}{9}cab^2+\frac{1}{3}abc^2+\frac{2}{11}a^2d$ $\frac{1}{4}bca^2+\frac{4}{13}c^2d+\frac{4}{9}cab^2$ and $\frac{9}{11}a^2d+\frac{3}{7}b^2d+\frac{9}{13}c^2d$

13. $\frac{x-2y}{2}+\frac{2y-3z}{6}+\frac{3z-4x}{12}$, $\frac{2x-3y}{6}+\frac{3y-4z}{12}+\frac{z-2x}{2}$ and $\frac{3x-4y}{12}+\frac{y-2z}{2}+\frac{2z-3x}{6}$.

14. $\frac{2x-3y}{6}+\frac{3y-5z}{15}+\frac{5z-7x}{35}$, $\frac{3x-5y}{15}+\frac{5y-7z}{35}+\frac{2z-3x}{6}$ and $\frac{5x-7y}{35}+\frac{2y-3z}{6}+\frac{3z-5x}{15}$.

15. $\frac{2b-3c}{bc}+\frac{3c-4a}{ca}+\frac{4a-2b}{ab}$, $\frac{2c-3a}{ca}+\frac{3a-4b}{ab}+\frac{4b-2c}{bc}$ and $\frac{2a-3b}{ab}+\frac{3b-4c}{bc}+\frac{4c-2a}{ca}$

16. $\frac{bx-3ay}{ab}+\frac{2by-4az}{ab}+\frac{3bz-ax}{ab}$, $\frac{cx-4by}{bc}+\frac{3cy-5bz}{bc}+\frac{4cz-bx}{bc}$ and $\frac{ax-2cy}{ca}+\frac{4ay-3cz}{ca}+\frac{5az-cx}{ca}$.

17. $\frac{cy-ax}{caxy}+\frac{az-by}{abyz}+\frac{bx-cz}{bczx}$, $\frac{ay-bx}{abxy}+\frac{bz-cy}{bcyz}+\frac{cx-az}{cazx}$ and $\frac{by-cx}{bcxy}+\frac{cz-ay}{cayz}+\frac{ax-bz}{abzx}$.

If $a=5$, $b=4$, $x=8$, $y=7$, find the numerical value of

18. $(46a^4+38b^4-87abx^2-105y^4)+(47abx^2+85y^4-56a^4-38b^4)+(57y^4+75b^4+23a^4+63abx^2)+(-33b^4+8y^4-27abx^2-39a^4)+(26a^4-45y^4-22b^4+5abx^2)$

19. $(35xy^4+207ab^4-98bx^4-62ya^4-83abx^2y)+(68bx^4+102ya^4-65xy^4-87ab^4+53abx^2y)+(26abx^2y-75ab^4-25ya^4+43bx^4+53xy^4)+(28ya^4-29xy^4-65abx^2y+45ab^4+26bx^4)+(-89ab^4-43ya^4+69abx^2y+6xy^4-39bx^4)$

20. $(57a^4bx+25b^4xy-143x^4ya+37y^4ab-253a^2b^2x^2)+(63x^4ya-92y^4ab-63a^4bx+73a^2b^2x^2-85b^4xy)+(35y^4ab+132b^4xy+82a^2b^2x^2+36x^4ya+96a^4bx)+(-50a^2b^2x^2-78a^4bx+27y^4ab-17x^4ya-52b^4xy)+(61x^4ya-20b^4xy+148a^2b^2x^2-7y^4ab-12a^4bx)$

Add together

21. $(a^2+b^2)(m+n)+(a^2-b^2)(p+q)+c^2l$ $(a^2-b^2)(m+n)+(a^2+b^2)(p+q)+c^2m$, $nc^2+l(a^2+b^2)+k(a^2-b^2)$

22. $(x+y)^2a+(y+z)^2b+(z+x)^2c$, $(x-y)^2a+(y-z)^2b+(z-x)^2c$ and $2(x^2-y^2)a+2(y^2-z^2)b+2(z^2-x^2)c$

23. $ab(a-b)$ $bc(b-c)$, $ca(c-a)$ and $a^2(c-b)+b^2(a-c)+c^2(b-a)$

Supply the following omissions

24. $a^2+b^2+c^2-ab-ac-bc$
$=\{\qquad\qquad\}-\{(b-c)^2+(c-a)^2+(a-b)^2\}$

25. $(b+c)x^2+(c+a)y^2+(a+b)z^2=\{\qquad\}-(ax^2+by^2+cz^2)$

II. Subtraction.

75. In Art 35, we have explained that to subtract a is the same as to add $-a$ Thus, $x-a=x+(-a)$ Similarly, to subtract an expression is to add it with its sign changed The ordinary rule for subtracting one compound expression from another has already been explained in Art 38, and has so far been applied to simple cases only We shall now consider harder examples on subtraction

Example 1. Subtract $ax+by+cz$
from $(b+c)y+(c+a)z+(a+b)x$

Arranging like terms in x, y and z and applying the rule explained in Art 38, the difference required is obtained Thus.

$$\begin{array}{lrrr} \text{The minuend} & =(a+b)x+ & (b+c)y+ & (c+a)z \\ \text{The subtrahend} & = \quad ax+ & by+ & cz \\ \hline \text{The difference} & = \quad bx+ & cy+ & az \end{array}$$

[In the remainder,
the co-efficient of $x=(a+b)-a=a+b-a=b$

Similarly, the co-efficients of y and z are c and a respectively]

Example 2. Subtract $(b-c)^2yz+(c-a)^2zx+(a-b)^2xy$
from $(b+c)^2yz+(c+a)^2zx+(a+b)^2xy$

$$\begin{array}{lrrr} \text{The minuend} & =(b+c)^2yz+ & (c+a)^2zx+ & (a+b)^2xy \\ \text{The subtrahend} & =(b-c)^2yz+ & (c-a)^2zx+ & (a-b)^2xy \\ \hline \therefore \text{The remainder} & = \quad 4bcyz+ & 4cazx+ & 4abxy \end{array}$$

[In the remainder,

$$\begin{aligned} \text{the co-efficient of } yz &= (b+c)^2-(b-c)^2 \\ &= b^2+2bc+c^2-(b^2-2bc+c^2) \\ &= b^2+2bc+c^2-b^2+2bc-c^2 \\ &= 4bc \end{aligned}$$

Similarly, the co-efficients of zx and xy are $4ca$ and $4ab$ respectively]

Example 3. Supply the omission in the following

$$(2a+3b)x+(3b+4c)y+(4c+2a)z$$
$$=(a+b)x+(b+c)y+(c+a)z+\{\qquad\qquad\}$$

Evidently, the omission can be obtained by subtracting $(a+b)x+(b+c)y+(c+a)z$ from $(2a+3b)x+(3b+4c)y+(4c+2a)z$. Proceeding as in examples 1 and 2 above, the result of subtraction can be easily found to be $(a+2b)x+(2b+3c)y+(3c+a)z$

Example 4. Subtract $2\cdot5ax-3\cdot7by-8\cdot32z$
from $3\frac{3}{4}ax+2\frac{4}{9}by+6\frac{83}{90}z$.

$$\begin{array}{ll} \text{The minuend} & =3\frac{3}{4}ax+2\frac{4}{9}by+6\frac{83}{90}z \\ \text{The subtrahend} & =2\cdot5ax-3\cdot7by-8\cdot32z \\ \hline \therefore \text{The remainder} & = \frac{5}{4}ax+\frac{56}{9}by+\frac{686}{45}z \end{array}$$

[In the remainder

the co-efficient of $x=3\frac{3}{4}-2.5=\frac{15}{4}-\frac{5}{2}=\frac{15-10}{4}=\frac{5}{4}$

the co-efficient of $y=2\frac{4}{9}-(-3.\dot{7})=2\frac{4}{9}+3.\dot{7}=\frac{22}{9}+\frac{34}{9}=\frac{56}{9}$,

the co-efficient of $z=6\frac{83}{90}-(-8.3\dot{2})=6\frac{83}{90}+8.3\dot{2}=\frac{623}{90}+\frac{749}{90}$
$=\frac{623+749}{90}=\frac{1372}{90}=\frac{686}{45}$]

Note *As in addition, fractional co-efficients in the remainder must be simplified by Rules of Arithmetic* [*See Ex 4*]

When compound expressions with brackets are to be subtracted it is more convenient to retain the brackets, as in Examples 1–3

EXERCISE 36.

Subtract

1. $-7x^5+6x^4y-8x^3y^2-13x^2y^3+9y^4$ from $3x^5-5x^4y+2x^3y^2-7x^2y^3+6y^4$

2. $3m^3nx-10n^3xm+14x^3mn-20m^2n^2x-27n^2x^2m$ from $5m^3nx-17n^3xm+26x^3mn-13m^2n^2x-19n^2x^2m$

3. $37x^6-28x^5y+43x^4y^2-54x^3y^3-67x^2y^4+84xy^5-93y^6$ from $48x^6-31x^5y-7x^4y^2-39x^3y^3-41x^2y^4+65xy^5-53y^6$

4. $-2yzbc^2+4yz^2bc-2ax^4-9y^2zbc+3a^2x^3$ from $3ax^4-5a^2x^3+6yzbc^2-7y^2zbc+8yz^2bc$

5. $19x^3z^5y-15x^3y^5z+27+11xyz^4-12x^2y^2z^2-19xy^3z^5$ from $25-16x^3y^5z-17xy^3z^5+21x^3z^5y-6x^2y^2z^2+8xyz^4$

6. $13x^3y^4z^2-23x^3y^2z^4+25x^4y^3z^2-66x^2y^4z^3+26x^2y^3z^4+35x^4y^2z^3$ from $29x^4y^3z^2-37x^3y^4z^2+54x^2y^3z^4-45x^3y^2z^4-67x^4y^2z^3+89x^2y^4z^3$.

7. $-29x^4y^3z^5+75x^5y^4z^3+13x^3y^5z^4+53x^3y^4z^5-94x^5y^3z^4-86x^4y^5z^3$ from $41x^3y^4z^5-87x^3y^5z^4-28x^4y^5z^3+63x^4y^3z^5-55x^5y^3z^4+37x^5y^4z^3$

8. What must be added to $3x^2-5xy+6y^2+7yz$ in order that the sum may be $-x^2-y^2-yz$?

9. What must be added to $-5x^3+13x^2y^2-a^2bx+5bxy^2+7xyab$ in order that the sum may be $x^3+x^2y^2+a^2bx-2bxy^2-2xyab$?

10. What must be added to $5x^4-6x^3y+7x^2y^2-8xy^3-19y^4$ in order that the sum may be $3x^4+5x^2y^2-12y^4$?

11. What must be added to $-5x^5-3x^4y+6x^3y^2+17x^2y^3+13xy^4-21y^5$ in order that the sum may be $-7x^5-4x^3y^2+13x^2y^3+29y^5$?

12. What must be subtracted from $2a^2+5ab-6b^2$ in order that the remainder may be a^2+2b^2 ?

13. What must be subtracted from $5x^2-6xy+4y^2-8x-10y+15$ in order that the remainder may be $x^2+2xy+3y^2+4x+5y+6$?

14. What must be subtracted from $3a^3-4a^2b+5ab^2-8b^3$ in order that the remainder may be $a^3-2ab^2+7b^3$?

15. What must be subtracted from $-8x^3y+4x^2y^2-11xy^3+12x^2-13y+27$ in order that the remainder may be $4x^3y-3x^2y^2-11xy^3+20x^2-30y+36$?

16. From what expression must $3a^2-7ab-8bc+9b^2$ be subtracted in order that the remainder may be $2a^2+3ab+3bc+2b^2$?

17. From what expression must $-3x^3+5y^2-7xy+8x-9$ be subtracted in order that the remainder may be $x^3-8y^2+2xy-11x+7$?

18. From what expression must $-7a^3-8b^2c-13ac^2+3b^3$ be subtracted in order that the remainder may be $4a^3-3b^2c+7ac^2-8b^3$?

19. From what expression must $21x^3-37xy^2+42y^3-18x^2+19xy-39$ be subtracted in order that the remainder may be $-25x^3+15xy^2-87y^3+7x^2-43xy+24$?

Subtract

20. $\frac{1}{12}x+\frac{97}{84}y+\frac{107}{57}z$ from $\frac{13}{24}x+\frac{213}{168}y+\frac{201}{19}z$

21. $-35ax+\frac{13}{56}y+17mz$ from $-\frac{1}{20}ax+\frac{3}{7}y+8mz$

22. $1.17a^2cx+2.31c^2by-63.18c^3z$ from $32.39c^2by+2.37a^2cx-62.73c^3z$

23. $\frac{32}{19}a^{\frac{1}{2}}c^{\frac{3}{2}}x+\frac{15}{22}a^{\frac{3}{2}}b^{\frac{5}{4}}y+\frac{21}{29}b^{\frac{3}{5}}c^{\frac{5}{12}}z+2.3lx+3.5my+\frac{3}{7}nz$

from $3.3lx+\frac{35}{44}a^{\frac{3}{2}}b^{\frac{5}{4}}y-\frac{3}{7}nz-\frac{8}{29}b^{\frac{3}{5}}c^{\frac{5}{12}}z-2.5my-\frac{65}{38}a^{\frac{1}{2}}c^{\frac{3}{2}}x$

24. Supply the omission in the following

(i) $3\ 2x+5\ 3y+5\ 4z-(\qquad\qquad)=2x+3y+6z$

(ii) $17x+23y+\frac{121}{21}z=52x-1\ 7y+\frac{40}{7}z-(\qquad\qquad)$,

(iii) $1\ 2a+15\ 52l^2+16m^2+14p$

$=(\qquad\qquad)-(2\ 2a+3\ 52l^2+4m^2+16p)$

Subtract ·

25. $bc(b-c)+ca(c-a)+ab(a-b)$
from $bc(b+c)+ca(c+a)+ab(a+b)$

26. $a^2(b-c)+b^2(c-a)+c^2(a-b)$
from $bc(b-c)+ca(c-a)+ab(a-b)$

27. $(b-c)^2+(c-a)^2+(a-b)^2$
from $2(a^2+b^2+c^2-ab-bc-ca)$

28. $(1+a+a^2)x+(1+b+b^2)y+(1+c+c^2)z$
from $(1+a)^2x+(1+b)^2y+(1+c)^2z$

29. A man earned $(ax+by+cz)$ rupees per month for a year and spent $(10ax+13cz)$ rupees during the same year How many rupees will he be left with at the end of the year ?

30. If out of $(50x+71y+18z)$ sheep, $(13x+12y)$ and $(15y+8z)$ be sold and $(3z+23x)$ die, find the number of sheep left

---

CHAPTER IX

HARDER MULTIPLICATION

76. We have explained the following rules for multiplication of Algebraic quantities in Chapter III

(1) $a\times b=b\times a$ [Art 42]

$abc=bca=cab$ etc [Art 43]

i e the value of a product is the same in whatever order the factors may be taken

This is called the **Commutative Law** of multiplication

(2) $(ab)\times c=a\times(bc)=b\times(ac)=a\times b\times c$ [Art 43]

i e, the factors of a product may be grouped in any way

This principle is known as **Associative Law** of multiplication

(3) $a(b+c)=ab+ac$ [Art 47]

This is known as **Distributive Law** of multiplication

(4) $a^m\times a^n=a^{m+n}$, where m and n are positive integers

This is known as **Index Law** of multiplication

We now proceed to consider products of compound expressions and harder examples on multiplication

77. To prove that $(a+b)(c+d)=ac+ad+bc+bd$.

Putting x for $c+d$, we have

$$\begin{aligned}(a+b)(c+d)&=(a+b)x=x(a+b)\\&=xa+xb \qquad\text{[Art 47]}\\&=ax+bx\\&=a(c+d)+b(c+d)\\&=ac+ad+bc+bd\end{aligned}$$

Cor. Since $a-b=a+(-b)$ and $c-d=c+(-d)$, therefore, $(a-b)(c-d)=\{a+(-b)\}\{c+(-d)\}=ac+a(-d)+(-b)c+(-b)(-d)$ $=ac-ad-bc+bd$

78. To prove that $(a+b+c+d+\cdots)(m+n+p+q+\cdots)$ $=a(m+n+p+q+\cdots)+b(m+n+p+q+\cdots)$ $+c(m+n+p+q+\cdots)+d(m+n+p+q+\cdots)+\&c.$

Putting x for $m+n+p+q\cdots$, we have

$$\begin{aligned}&(a+b+c+d+\cdots)(m+n+p+q+\cdots)\\&\quad=(a+b+c+d+\cdots)x\\&\quad=ax+bx+cx+dx+\cdots\\&\quad=a(m+n+p+q+\cdots)+b(m+n+p+q+\cdots)\\&\qquad+c(m+n+p+q+\cdots)+d(m+n+p+q+\cdots)+\&c\end{aligned}$$

Thus to multiply one multinominal expression by another we have to multiply every term of the one by every term of the other and take the algebraic sum of these partial products

Example 1. Multiply $2a+3b$ by $4a+5b$

$$\begin{aligned}(4a+5b)(2a+3b)&=(4a)(2a)+(4a)(3b)+(5b)(2a)+(5b)(3b)\\&=8a^2+12ab+10ab+15b^2\\&=8a^2+22ab+25b^2\end{aligned}$$

Example 2. Multiply $3x-7y$ by $2x-5y$

$$\begin{aligned}(2x-5y)(3x-7y)&=(2x)(3x)+(2x)(-7y)+(-5y)(3x)+(-5y)(-7y)\\&=6x^2-14xy-15xy+35y^2\\&=6x^2-29xy+35y^2\end{aligned}$$

EXERCISE 37.

Multiply

1. $2a+3b$ by $a+b$ **2.** $2m-3n$ by $m-n$

3. $a+b+c$ by $a+b+c$ **4.** $a-b+c$ by $a-b+c$

5. $a-b-c$ by $a-b-c$ **6.** $a-2b-3c$ by $2a-b-c$

7. $2x-3y-4z$ by $x-y-z$

8. $-5x+2a-3b$ by $-x-a+b$

9. $x^2+y^2+z^2$ by $x-y-z$

10. $xy+yz+zx$ by $xy-yz-zx$

79. Arrangement of an expression according to descending or ascending powers of some letter.

When the different terms of an expression contain different powers of any letter, if we arrange the terms in such a way that the term containing the highest power of that letter is put first on the left, the term containing the next highest power is put next, and so on, and the term which either contains the lowest power of that letter, or does not contain that letter at all is put last, then we are said to arrange the expression according to **descending** powers of the letter considered If the order of the terms be reversed the arrangement is said to be according to **ascending** powers of the letter Thus the expression $a^5x^3+3a^4xy-5a^3x^6y^2+4a^2x^4y^3-2ax^2y^4+x^5y^5$ as it stands may be considered as arranged either according to *descending* powers of a, or according to *ascending* powers of y, but if it is arranged as $-5a^3x^6y^2+x^5y^5+4a^2x^4y^3+a^5x^3-2ax^2y^4+3a^4xy$, it is arranged according to descending powers of x

80. When one expression is to be multiplied by another arrange both the multiplicand and the multiplier according to descending or ascending powers of some letter common to them, and proceed as exemplified below

Example 1. Multiply a^2-b^2-ab by $ab-b^2+a^2$

$$\begin{array}{llllll}
\text{Multiplicand} & =a^2-ab & -b^2 & & & \\
\text{Multiplier} & =a^2+ab & -b^2 & & & \\
\hline
\text{Product by } a^2 & =a^4-a^3b & -a^2b^2 & & & \\
\text{Product by } +ab= & \quad +a^3b & -a^2b^2 & -ab^3 & & \\
\text{Product by } -b^2= & & -a^2b^2 & +ab^3 & +b^4 & \\
\hline
\text{Complete product}= & a^4 & -3a^2b^2 & & +b^4 &
\end{array}$$

Note *The process shown above may be described as follows*

The multiplier has been placed under the multiplicand after having arranged them both according to descending powers of a, and a line has been drawn below the multiplier The successive products of the multiplicand by the different terms of the multiplier beginning from the left have been placed in different horizontal rows in such a manner that each set of like terms may be in the same vertical column A line having been now drawn below the lowest of the rows, the complete product has been found by writing down the sum of each vertical column immediately below it

Example 2. Multiply $2a^2-3x^2-5ax$ by $-3x^2+2a^2+5ax$

Arranging the multiplicand and the multiplier according to ascending powers of x, we have

$$\begin{array}{llllll}
\text{Multiplicand} & =2a^2-5ax-3x^2 & & & & \\
\text{Multiplier} & =2a^2+5ax-3x^2 & & & & \\
\hline
& 4a^4-10a^3x & -6a^2x^2 & & & \\
& \quad +10a^3x & -25a^2x^2 & -15ax^3 & & \\
& & -6a^2x^2 & +15ax^3 & +9x^4 & \\
\hline
\text{Product} & =4a^4 & -37a^2x^2 & & +9x^4 &
\end{array}$$

Example 3. Multiply $2a^3b-5ab^3-a^4+3a^2b^2$

by $2a^4-3a^3b+4ab^3-5a^2b^2$

Arranging the multiplicand and the multiplier according to descending powers of x, we have

$$
\begin{array}{rl}
\text{Multiplicand} & = -a^4+2a^3b+3a^2b^2-5ab^3 \\
\text{Multiplier} & = 2a^4-3a^3b-5a^2b^2+4ab^3 \\
\hline
& -2a^8+4a^7b+6a^6b^2-10a^5b^3 \\
& \qquad +3a^7b-6a^6b^2-9a^5b^3+15a^4b^4 \\
& \qquad\qquad +5a^6b^2-10a^5b^3-15a^4b^4+25a^3b^5 \\
& \qquad\qquad\qquad -4a^5b^3+8a^4b^4+12a^3b^5-20a^2b^6 \\
\hline
\text{Product} & = -2a^8+7a^7b+5a^6b^2-33a^5c^3+8a^4b^4+37a^3b^5-20a^2b^6
\end{array}
$$

Note *In this example the multiplicand and the multiplier are each homogeneous and of the 4th degree, whilst the product also is homogeneous and of the 8th degree Similarly, it may be seen that whenever the expressions to be multiplied together are homogeneous, the product also is homogeneous, and the degree of the product is equal to the sum of the degrees of the expressions This law is of great importance in testing the accuracy of a multiplication when the multiplicand and the multiplier are both homogeneous, for in this case if the product obtained does not turn out to be homogeneous, we are sure there has been an error somewhere*

Example 4. Multiply mx^2-nx-p by x^2+px-1

$$
\begin{array}{rl}
\text{Multiplicand} & = mx^2-nx-p \\
\text{Multiplier} & = x^2+px-1 \\
\hline
& mx^4-nx^3-px^2 \\
& \qquad +pmx^3-pnx^2-p^2x \\
& \qquad\qquad -mx^2+nx+p \\
\hline
\text{Product} & = mx^4-(n-pm)x^3-(p+pn+m)x^2+(n-p^2)x+p
\end{array}
$$

Example 5. Multiply $\frac{11}{6}ax^3+\frac{7}{19}b^2x^2y+3.5cxy^2+1.05g^2y^2$ by $2lx^2+3.5mxy+1.5ny^2$

[N B To find the product of expressions in which both vulgar fractions and decimal fractions occur as co-efficients, it is convenient to reduce all the co-efficients to fractions of the same kind (either all vulgar or all decimal) and apply the rule of multiplication]

In this example, as $\frac{7}{19}$, when reduced to a decimal fraction, will involve a very large number of decimal places, we reduce all the co-efficients of the multiplicand as also of the multiplier to vulgar fractions

$$
\begin{array}{l}
\text{Multiplicand} = \frac{11}{5}ax^3 + \frac{7}{19}b^2x^2y + \frac{7}{2}cxy^2 + \frac{21}{20}g^2y^3 \\
\text{Multiplier} \quad = 2lx^2 + \frac{7}{2}mxy + \frac{3}{2}ny^2 \\
\hline
\frac{22}{5}alx^5 + \frac{14}{19}b^2lx^4y + \quad 7clx^3y^2 + \frac{21}{10}g^2lx^2y^3 \\
\qquad + \frac{77}{10}amx^4y + \frac{49}{38}b^2mx^3y^2 + \frac{49}{4}cmx^2y^3 + \frac{147}{40}g^2mxy^4 \\
\qquad\qquad + \frac{33}{10}anx^3y^2 + \frac{21}{38}b^2nx^2y^3 + \frac{21}{4}cnxy^4 + \frac{63}{40}g^2ny^5 \\
\hline
\end{array}
$$

$$
\begin{aligned}
\text{Product} = {} & \tfrac{22}{5}alx^5 + \left(\tfrac{14}{19}b^2l + \tfrac{77}{10}am\right)x^4y + \left(7cl + \tfrac{49}{38}b^2m + \tfrac{33}{10}an\right)x^3y^2 \\
& + \left(\tfrac{21}{10}g^2l + \tfrac{49}{4}cm + \tfrac{21}{38}b^2n\right)x^2y^3 + \left(\tfrac{147}{40}g^2m + \tfrac{21}{4}cn\right)xy^4 + \tfrac{63}{40}g^2ny^5
\end{aligned}
$$

Example 6. Multiply together a^2-ab+b^2, a^2+ab+b^2 and $a^4-a^2b^2+b^4$

(i)

$$
\begin{array}{l}
a^2-ab+b^2 \\
\underline{a^2+ab+b^2} \\
a^4-a^3b+a^2b^2 \\
\qquad +a^3b-a^2b^2+ab^3 \\
\qquad\qquad +a^2b^2-ab^3+b^4 \\
\hline
a^4 \qquad +a^2b^2 \qquad +b^4 ,
\end{array}
$$

(ii)

$$
\begin{array}{l}
a^4+a^2b^2+b^4 \\
\underline{a^4-a^2b^2+b^4} \\
a^8+a^6b^2+a^4b^4 \\
\qquad -a^6b^2-a^4b^4-a^2b^6 \\
\qquad\qquad +a^4b^4+a^2b^6+b^8 \\
\hline
a^8 \qquad +a^4b^4 \qquad +b^8
\end{array}
$$

Thus the required product $=a^8+a^4b^4+b^8$

Note *When the number of factors in a product is* ***more than two,*** *the product is called the* ***continued product*** *of those factors*

The factors should be arranged in a suitable order so as to lessen the trouble of multiplication in such products

81. Detached Co-efficients. If both the multiplier and the multiplicand contain powers of the same algebraic quantity or be homogeneous expressions of the same quantities, the labour of multiplication may be lessened by detaching the co-efficients and placing them in proper relative positions *If any power be missing, zero must be inserted as its co-efficient*

The following examples will illustrate the process

Example 1. Multiply x^2-4x+4 by $x-2$

$$\begin{array}{l}
x^2-4x+4 \\
x\ -2 \\
\hline
\ 1-4\ \ +4 \\
\quad -2\ +8-8 \\
\hline
\end{array}$$

The product$=x^3-6x^2+12x-8$

Example 2. Multiply $3x^3-2x+4$ by $x+5$

$$\begin{array}{l}
3x^3+0\,x^2-2x+4 \\
\quad x+5 \\
\hline
\quad 3+\ 0\quad -2\ +\ 4 \\
\qquad +15\quad -0\ -10\ +20 \\
\hline
\end{array}$$

The product$=3x^4+15x^3-2x^2-6x+20$

EXERCISE 38.

Multiply

1. $25b^2+30ab+9a^2$ by $3a-5b$
2. $2a-3b+4c$ by $2a+3b-4c$
3. x^2-x+2 by x^2+x+2
4. $a^2-2ab+b^2$ by $a^2+2ab+b^2$
5. x^4+x^2+1 by x^4-x^2+1
6. $y^3-x^2y^2+x^3$ by $x^3+x^2y^2+y^3$
7. $m^4-m^2n^2+n^4$ by m^2+n^2
8. $p^2q^2+p^4+q^4$ by $-q^2+p^2$
9. $a^3+5ab^2-6a^2b$ by $5b^2+a^2+6ab$
10. x^3-3x^2+3x-1 by x^2+3x+1
11. $2ax^3+a^4+3a^2x^2+x^4+2a^3x$ by a^2+x^2-2ax
12. $a^3+3a^2b+b^3+3ab^2$ by $3ab^2-b^3+a^3-3a^2b$
13. $x^2-11+x^4-4x+2x^3$ by $3+x^2-2x$
14. $1+2x+x^4+2x^3+3x^2$ by $1+x^2-2x$
15. $b^4+a^2b^2+a^3b+a^4+ab^3$ by $a^2b^2-a^3b+b^4-ab^3+a^4$.
16. $x^2-xy-xz+y^2-yz+z^2$ by $x+y+z$

17. $a^2+b^2+c^2-bc-ca-ab$ by $a+b+c$

18. $5a^2b+4b^3+2a^3-3ab^2$ by $2ab^2-3a^2b+a^3-5b^3$

19. ax^2+bx-c by $px-q$ **20.** mx^2-nx-r by $nx-r$

21. ax^2-bx+c by x^2-bx-c.

22. ax^3-bx^2+cx-d by bx^2-cx+d

23. $px^2-(q-r)x+s$ by mx^2-nx-s

24. $ax^2+2hxy+by^2$ by $lx+my+n$

25. $l^2x^2+m^2xy+n^2y^2+2g^2x+2f^2y+c^2$ by px^2+qx+r

26. $\frac{7}{9}x^3+\frac{2}{5}x^2y+\frac{3}{5}xy^2+\frac{3}{7}y^3$ by $\frac{9}{7}x^2+\frac{5}{3}xy+\frac{7}{3}y^2$

27. $\frac{3}{7}x^4+\frac{5}{7}x^3y+\frac{9}{7}x^2y^2+\frac{1}{7}xy^3+\frac{11}{7}y^4$ by $\frac{7}{3}x^2+\frac{7}{11}y^2$

28. $1{\cdot}5x^5+2{\cdot}3x^9+1{\cdot}23x^4+3{\cdot}25x^2+5$ by $27x^3+1{\cdot}39x+9$

29. ${\cdot}057a^3+1{\cdot}025a^2b+2{\cdot}021ab^2+2{\cdot}8b^3$ by $7a^2+2ab+9b^2$

30. $2{\cdot}3x^3+3{\cdot}15x^2y+1{\cdot}17xy^2+2{\cdot}07y^3$ by $lx^2+mxy+ny^2$

31. $\frac{5}{2}ax^3+\frac{7}{3}bx^2y+\frac{9}{4}cxy^2+2dy^3$ by $\frac{2}{5}ax^2-\frac{3}{7}bxy+\frac{4}{9}cy^2$

32. $1{\cdot}5am^3-1{\cdot}2bm^2n+1{\cdot}3cmn^2-1{\cdot}6dn^3$
by $1{\cdot}5am^3+1{\cdot}2bm^2n+1{\cdot}3cmn^2+1{\cdot}6dn^3$

Find the continued product of

33. $2a+3b$, $2a-3b$ and $4a^2+9b^2$

34. $5ax+6by$, $5ax-6by$ and $25a^2x^2+36b^2y^2$

35. $x^8+x^4y^4+y^8$, x^2+y^2, $x+y$ and $x-y$

36. $x^2+3xy+5y^2$, $x^2-3xy+5y^2$ and $x^4-x^2y^2+25y^4$

37. $a^{12}x^{12}+a^6b^6x^6y^6+b^{12}y^{12}$, $a^4x^4+a^2b^2x^2y^2+b^4y^4$, $ax+by$ and $ax-by$

Assuming $a^m\times a^n=a^{m+n}$ to be true for *all* values of m and n, prove that

38. $a^{\frac{1}{2}}\times a^{\frac{1}{2}}=a$ $\left[a^{\frac{1}{2}}\times a^{\frac{1}{2}}=a^{\frac{1}{2}+\frac{1}{2}}=a^1=a\right]$

39. $x^{\frac{1}{3}}\times x^{\frac{2}{3}}=x$

40. $a^{\frac{1}{3}}\times a^{\frac{1}{3}}\times a^{\frac{1}{3}}=a$ $\left[a^{\frac{1}{3}}\times a^{\frac{1}{3}}\times a^{\frac{1}{3}}=a^{\frac{1}{3}+\frac{1}{3}+\frac{1}{3}}=a^1=a\right]$

41. $a^{\frac{1}{4}}=\sqrt[4]{a}$

$\left[\left(a^{\frac{1}{4}}\right)^4=a^{\frac{1}{4}}\times a^{\frac{1}{4}}\times a^{\frac{1}{4}}\times a^{\frac{1}{4}}=a^{\frac{1}{4}+\frac{1}{4}+\frac{1}{4}+\frac{1}{4}}=a^1=a,\quad a^{\frac{1}{4}}=\sqrt[4]{a}\right]$

42. $x^{\frac{2}{3}} = \sqrt[3]{x^2}$ **43.** $z^{\frac{3}{4}} = \sqrt[4]{z^3}$

44. $c^{\frac{3}{5}} \times c^{\frac{4}{5}} \times c^{\frac{8}{5}} = c^3$ **45.** $y^2 \times y^{\frac{3}{2}} \times y^{\frac{7}{2}} = y^7$

46. $x^{-2} \times x^5 = x^3$ $[x^{-2} \times x^5 = x^{-2+5} = x^3]$

47. $z^{\frac{3}{2}} \times z^{-\frac{1}{2}} = z$ **48.** $a^{-\frac{3}{2}} = \sqrt{a^{-3}}$

$\left[\left(a^{-\frac{3}{2}}\right)^2 = a^{-\frac{3}{2}} \times a^{-\frac{3}{2}} = a^{-\frac{3}{2}-\frac{3}{2}} = a^{-3}, \quad a^{-\frac{3}{2}} = \sqrt{a^{-3}}\right]$

49. $b^{-\frac{5}{3}} = \sqrt[3]{b^{-5}}$ **50.** $x^{-\frac{5}{3}} \times x^{-\frac{4}{3}} = x^{-3}$

Write down the product of

51. $-3x^{\frac{1}{2}}$ and $2x^{\frac{3}{2}}$ **52.** $5y^{\frac{1}{2}}$ and $-\frac{2}{5}y^{\frac{5}{2}}$

53. $2x^{\frac{1}{2}}y^{\frac{1}{2}}$ and $3x^{\frac{3}{2}}y^{\frac{1}{2}}$ **54.** $-5xy^{\frac{3}{4}}$ and $-3x^{\frac{2}{3}}y^{\frac{1}{2}}$

55. $4a^{-2}b^3$ and $-\frac{3}{4}a^3b^{-5}$ **56.** $\frac{3}{5}a^{\frac{3}{5}}y^3$ and $-\frac{5}{4}a^{\frac{2}{5}}y^{-4}$

57. $-4a^{\frac{1}{2}}b^{\frac{2}{3}}c^{\frac{3}{4}}$ and $-3a^{\frac{3}{2}}b^{\frac{4}{3}}c^{\frac{5}{4}}$

58. $-5x^{\frac{2}{3}}y^{\frac{3}{5}}z^{\frac{4}{3}}$ and $-3x^{\frac{1}{3}}y^{\frac{2}{5}}z^{-\frac{1}{3}}$

59. $-6a^{\frac{5}{3}}b^{-\frac{3}{4}}c^{-\frac{2}{7}}$ and $5a^{\frac{1}{3}}b^{\frac{7}{4}}c^{-\frac{5}{7}}$

60. $-4a^{\frac{5}{6}}x^{\frac{5}{3}}y^{-\frac{4}{5}}$ and $-19a^{\frac{1}{2}}x^{-\frac{3}{2}}y^{-\frac{6}{5}}$

Multiply

61. $a^{\frac{1}{2}}+b^{\frac{1}{2}}$ by $a^{\frac{1}{2}}+b^{\frac{1}{2}}$ **62.** $a^{\frac{1}{2}}-b^{\frac{1}{2}}$ by $a^{\frac{1}{2}}-b^{\frac{1}{2}}$

63. $3x^{\frac{2}{3}}-4y^{\frac{1}{3}}$ by $3x^{\frac{2}{3}}+4y^{\frac{1}{3}}$ **64.** $a^{\frac{2}{3}}-a^{\frac{1}{3}}b^{\frac{1}{3}}+b^{\frac{2}{3}}$ by $a^{\frac{1}{3}}+b^{\frac{1}{3}}$

65. $x^{\frac{2}{3}}+x^{\frac{1}{3}}y^{\frac{1}{3}}+y^{\frac{2}{3}}$ by $x^{\frac{1}{3}}-y^{\frac{1}{3}}$

66. $a^{\frac{3}{2}}-a^{\frac{3}{4}}b^{\frac{3}{4}}+b^{\frac{3}{2}}$ by $a^{\frac{3}{2}}+a^{\frac{3}{4}}b^{\frac{3}{4}}+b^{\frac{3}{2}}$

67. $2x^{\frac{4}{3}}-5x^{\frac{2}{3}}y^{\frac{2}{3}}-3y^{\frac{4}{3}}$ by $2x^{\frac{4}{3}}+5x^{\frac{2}{3}}y^{\frac{2}{3}}-3y^{\frac{4}{3}}$

68. $a^{\frac{5}{2}}+a^2b^{\frac{1}{3}}+a^{\frac{3}{2}}b^{\frac{2}{3}}+ab+a^{\frac{1}{2}}b^{\frac{4}{3}}+b^{\frac{5}{3}}$ by $a^{\frac{1}{2}}-b^{\frac{1}{3}}$

69. $x^{\frac{3}{2}}-xy^{\frac{1}{2}}+x^{\frac{1}{2}}y-y^{\frac{3}{2}}$ by $x^{\frac{1}{2}}+y^{\frac{1}{2}}$

70. $a^{\frac{3}{4}}+a^{\frac{1}{2}}b^{\frac{1}{2}}+a^{\frac{1}{4}}b+b^{\frac{3}{2}}$ by $a^{\frac{1}{4}}-b^{\frac{1}{2}}$

71. $x^{\frac{2}{3}}+y^{\frac{2}{3}}+z^{\frac{2}{3}}-x^{\frac{1}{3}}y^{\frac{1}{3}}-y^{\frac{1}{3}}z^{\frac{1}{3}}-z^{\frac{1}{3}}x^{\frac{1}{3}}$ by $x^{\frac{1}{3}}+y^{\frac{1}{3}}+z^{\frac{1}{3}}$

72. $a^{2n}-a^nx^n+x^{2n}$ by a^n+x^n

73. $a^{-3}-4a^{-2}b+4a^{-1}b^2-b^3$ by $a^{-2}-2a^{-1}b+b^2$

74. $x^{-3}+3x^{-\frac{3}{2}}y^{\frac{3}{2}}+2y^3$ by $x^{-3}-3x^{-\frac{3}{2}}y^{\frac{3}{2}}+2y^3$

75. $2a^{-5}+3a^{-\frac{5}{2}}b^{-\frac{3}{2}}-5b^{-3}$ by $2a^{-5}+3a^{-\frac{5}{2}}b^{-\frac{3}{2}}+5b^{-3}$

Apply the method of detached co-efficients to find the product of:

76. $2x^2+3x+9$ and $3x+5$

77. $x^2-2x-15$ and $2x-3$

78. $3x^3+5x+6$ and x^2+3x+2

79. x^2+px+r by $px+q$

80. $\frac{1}{3}x^4+\frac{3}{2}x^2+5$ by $\frac{3}{2}x^2+x+2$

CHAPTER X

HARDER DIVISION

82. The principal rules for division explained in Chapter III, may be stated as follows

(i) $a \div b = a \times \frac{1}{b}$;

(ii) $a \div b \div c = a \div bc$;

(iii) $a \div b \times c = a \times c \div b$,

and (iv) $a^m \div a^n = a^{m-n}$, where m and n are positive integers and $m > n$

The rule (iv) is called the **Index Rule** for division

The **Law of Signs** and the rule for division of a monomial or a multinomial expression by a monomial have been explained in Arts 50-52 We now propose to consider division of one multinomial expression by another

83. Division of one multinomial expression by another.

Let us consider a particular example

We have $(2a^2+3ab+4b^2)(a+3b)$

$$=2a^2(a+3b)+3ab(a+3b)+4b^2(a+3b)$$

$$=2a^3+9a^2b+13ab^2+12b^3$$

Hence, $(2a^3+9a^2b+13ab^2+12b^3)\div(a+3b)$

$$=2a^2+3ab+4b^2$$

Now, let us review this result and see in what way, given the dividend and the divisor, we can discover the quotient The points noticed are

(i) The dividend and the divisor *both* stand arranged according to descending powers of a common letter, namely, a

(ii) The *first* term of the quotient, namely, $2a^2=2a^3\div a$, *i e* =(the 1st term of the dividend)÷(the 1st term of the divisor)

(iii) If we subtract $2a^2(a+3b)$ from the dividend, the remainder is $3a^2b+13ab^2+12b^3$, and the *second* term of the quotient, namely, $3ab=3a^2b\div a$, *i e* =(the 1st term of this remainder)÷(the 1st term of the divisor)

(iv) If we subtract $3ab(a+3b)$ from the above remainder, the new remainder is $4ab^2+12b^3$, and the *third* term of the quotient namely, $4b^2=4ab^2\div a$, *i e*,=(the 1st term of this remainder)÷(the 1st term of the divisor)

(v) If we subtract $4b^2(a+3b)$ from the preceding remainder, nothing remains and the division is complete

The process noted above can be shown as follows

$$\begin{array}{r|l|l}
a+3b & 2a^3+9a^2b+13ab^2+12b^3 & 2a^2+3ab+4b^2 \\
 & \underline{2a^3+6a^2b} & \\
 & 3a^2b+13ab^2+12b^3 & \\
 & \underline{3a^2b+\ \ 9ab^2} & \\
 & 4ab^2+12b^3 & \\
 & \underline{4ab^2+12b^3} & \\
\end{array}$$

Hence we deduce the following rule

Arrange both the dividend and the divisor according to the descending powers of some common letter and place them in a line as in the process of Division in Arithmetic

Divide the first term of the dividend by the first term of the divisor and write down the result as the first term of the quotient Multiply the divisor by the quantity thus found and subtract the product from the dividend

Regard the remainder as a new dividend and see if it is arranged according to the descending powers of the common letter. Divide its first term by the first term of the divisor and write down the result as the next term of the quotient Multiply the divisor by this term and subtract the product from the new dividend

Then go on similarly with the successive remainders until there is no remainder

Note *That the rule stated above gives us a correct result is evident For, the different quantities, that are one by one subtracted from the dividend, being the partial products of the divisor by successive terms of the quotient, their sum is equal to the product of the divisor by the* ***whole*** *quotient, and as this sum is clearly equal to the dividend, the dividend is equal to the product of the divisor by the quotient, and* ***this is what it should be***

Example 1. Divide $x^4-4x^2+12x-9$ by x^2-2x+3

Both the dividend and the divisor, as they are, are arranged according to descending powers of x Hence, we may proceed at once as follows

$$
\begin{array}{r|rrrrr|l}
x^2-2x+3 & x^4 & & -4x^2 & +12x & -9 & x^2+2x-3 \\
 & x^4 & -2x^3 & +3x^2 & & & \\
\hline
 & & 2x^3 & -7x^2 & +12x & -9 & \\
 & & 2x^3 & -4x^2 & +6x & & \\
\hline
 & & & -3x^2 & +6x & -9 & \\
 & & & -3x^2 & +6x & -9 & \\
\hline
\end{array}
$$

Thus the required quotient $=x^2+2x-3$

Note *In the dividend it must be noticed that the term containing* x^3 *is wanting and hence the second term which contains* x^2, *has been put a little apart from the first as if leaving unoccupied the place of the absent term. This point should be attended to, although not strictly required,* ***for the purpose of having like terms placed under one another ;*** *for instance, in the above example if the second term*

of the dividend, stood close to the first, $-2x^3$ *would come under* $-4x^2$*, and* $3x^2$ *under* $12x$*, and this might confuse the beginner or otherwise lessen the neatness of the process*

Example 2. Divide $16x^4+36x^2+81$ by $4x^2+6x+9$

$$\begin{array}{r|llll|l}
4x^2+6x+9 & 16x^4 & & +36x^2 & +81 & 4x^2-6x+9 \\
 & 16x^4 & +24x^3 & +36x^2 & & \\ \hline
 & & -24x^3 & & +81 & \\
 & & -24x^3 & -36x^2 & -54x & \\ \hline
 & & & 36x^2 & +54x+81 & \\
 & & & 36x^2 & +54x+81 & \\ \hline
\end{array}$$

Thus, the required quotient $=4x^2-6x+9$

Example 3. Divide $x^6-4x^4-2x^3+3x^2+8x-12$ by x^2-4

*N B It is not **essential** to arrange the dividend and the divisor according to **descending** powers of some letter common to them, the arrangements may as well be according to **ascending** powers of that letter The only thing indispensable is that **both the expressions** should be arranged in the **same** order, be it descending or ascending For instance, let us work out the present example by arranging the expressions in the **ascending** order of the powers of x*

$$\begin{array}{r|llll|l}
-4+x^2 & -12+8x & +3x^2-2x^3 & -4x^4+x^6 & & 3-2x+x^4 \\
 & -12 & +3x^2 & & & \\ \hline
 & 8x & -2x^3 & -4x^4+x^6 & & \\
 & 8x & -2x^3 & & & \\ \hline
 & & & -4x^4+x^6 & & \\
 & & & -4x^4+x^6 & & \\ \hline
\end{array}$$

Thus, the required quotient $=3-2x+x^4$

Example 4. Divide $a^2b^2+2abc^2-a^2c^2-b^2c^2$ by $ab+ac-bc$

The dividend when arranged according to descending powers of a becomes, $(b^2-c^2)a^2+2bc^2a-b^2c^2$

The divisor, when so arranged becomes $(b+c)a-bc$

Thus, the dividend has become a trinomial and the divisor a binomial

$$\begin{array}{r|lll|l}
(b+c)a-bc & (b^2-c^2)a^2 & +2bc^2\,a & -b^2c^2 & (b-c)a+bc \\
 & (b^2-c^2)a^2 & -(b^2c-bc^2)a & & \\ \hline
 & & (b^2c+bc^2)a & -b^2c^2 & \\
 & & (b^2c+bc^2)a & -b^2c^2 & \\ \hline
\end{array}$$

Thus, the required quotient $=ab-ac+bc$

Example 5. Divide $a^3+b^3-c^3+3abc$ by $a+b-c$

The dividend and the divisor, arranged according to descending powers of a, become respectively

$$a^3+3bc\,a+(b^3-c^3) \text{ and } a+(b-c)$$

Thus, the dividend has become a trinomial and the divisor a binomial

$$\begin{array}{l|l|l}
a+(b-c) & a^3 \qquad\qquad +3bc\,a+(b^3-c^3) & a^2-(b-c)a+(b^2+bc+c^2) \\
 & \underline{a^3+(b-c)a^2} & \\
 & -(b-c)a^2+3bc\,a+(b^3-c^3) & \\
 & \underline{-(b-c)a^2-(b-c)^2\,a} & \\
 & (b^2+bc+c^2)a+(b^3-c^3) & \\
 & \underline{(b^2+bc+c^2)a+(b^3-c^3)} &
\end{array}$$

Thus, the required quotient $=a^2+b^2+c^2-ab+ac+bc$

Example 6. Divide $(b-c)a^3+(c-a)b^3+(a-b)c^3$ by $a^2-ab-ac+bc$

Let us arrange the dividend and the divisor according to descending powers of a

The dividend $=(b-c)a^3-b^3a+c^3a+b^3c-bc^3$

$=(b-c)a^3-(b^3-c^3)a+bc(b^2-c^2)$

The divisor $=a^2-(b+c)a+bc$

Thus, the dividend has become a trinomial and the divisor also a trinomial

$$\begin{array}{l|l|l}
a^2-(b+c)a+bc & (b-c)a^3-(b^3-c^3)a\;+bc(b^2-c^2) & (b-c)a \\
 & \underline{(b-c)a^3-(b^2-c^2)a^2+bc(b-c)a} & \quad +(b^2-c^2) \\
 & (b^2-c^2)a^2-(b^3+b^2c-bc^2-c^3)a+bc(b^2-c^2) & \\
 & \underline{(b^2-c^2)a^2-(b^3+b^2c-bc^2-c^3)a+bc(b^2-c^2)} &
\end{array}$$

Thus, the required quotient $=ab-ac+b^2-c^2$

Note *It must be noted that the expressions which are enclosed with brackets as co-efficients of different powers of a are all arranged according to descending powers of b Such arrangements add to the neatness of the process and lessen the chance of confusion*

EXERCISE 39.

Divide

1. $x^2-9x-14$ by $x-7$ **2.** $3x^2-17x+10$ by $3x-2$

3. $12x^2-8x-32$ by $4x-8$ **4.** $55x^2-67x-14$ by $11x+2$.

5. $2a^2-7ab+6b^2$ by $a-2b$

6. $x^4+x^2y^2+y^4$ by x^2+xy+y^2

7. $4x^2-9a^2$ by $2x+3a$ **8.** x^3+a^3 by $x+a$

9. $a^3-a^2b-7ab^2+3b^3$ by $a-3b$

10. $\frac{1}{2}x^3+\frac{23}{10}x^2+\frac{47}{5}x+18$ by $\frac{1}{2}x^2+\frac{4}{5}x+6$

11. $\frac{3}{2}x^3-\frac{15}{8}x^2+\frac{65}{48}x-\frac{5}{12}$ by $\frac{3}{4}x^2-\frac{9}{16}x+\frac{5}{12}$

12. $\frac{1}{6}a^3y^3-\frac{5}{24}a^2y^2b+\frac{67}{432}ayb^2-\frac{5}{108}b^3$ by $\dfrac{a^2}{12}y^2-\dfrac{ab}{16}y+\frac{5}{108}b^2$

13. $\frac{7}{2}a^3m^3+\frac{161}{10}a^2m^2n+\frac{294}{5}amn^2+126n^3$
by $\frac{7}{2}a^2m^2+\frac{28}{5}amn+42n^2$

14. $\frac{4}{9}x^4-x^2y^2+\frac{8}{3}xy^3-\frac{16}{9}y^4$ by $\frac{2}{9}x^2-\dfrac{xy}{3}+\frac{4}{9}y^2$

15. $\frac{1}{7}y^5-\frac{3}{7}xy^4+\frac{2}{21}x^2y^3+\frac{5}{21}x^3y^2-\frac{1}{3}x^4y+\frac{2}{21}x^5$
by $\frac{1}{21}y^2-\frac{1}{7}xy+\frac{1}{21}x^2$

16. $\frac{13}{12}mn^3+\frac{1}{6}m^2n^2+\dfrac{m^4}{2}-\frac{1}{12}m^3n+\frac{1}{3}n^4$ by $\frac{1}{6}mn+\frac{1}{8}m^2+\frac{1}{24}n^2$

17. $\frac{2}{3}a^2y^3+\frac{1}{4}y^5+\dfrac{a^5}{12}-\frac{3}{4}a^3y^2-\frac{1}{6}ay^4-\frac{1}{12}a^4y$
by $\frac{1}{6}ay-\frac{1}{4}y^2+\frac{1}{12}a^2$

18. If $x+y+z=-3a$, find the quotient when $(2x-y-z)(2y-z-x)(2z-x-y)$ is divided by $a^2+a(x+y)+xy$

Divide

19. $\frac{1}{3}[(x-y)^3+(y-z)^3+(z-x)^3]$ by $(x-y)(y-z)$

20. $x^6-2a^3x^3+a^6$ by $x^2-2ax+a^2$

21. $2x^3y^3+y^6+x^6$ by $2xy+x^2+y^2$

22. $x^3+(a+b+c)x^2+(ab+ac+bc)x+abc$ by $x+c$

23. $x^3+(b-c-a)x^2+(ca-ab-bc)x+abc$
by $x^2+(b-a)x-ab$

24. $a^3+a^2b+a^2c-abc-b^2c-bc^2$ by a^2-bc

25. $a^2(b+c)-b^2(c+a)+c^2(a+b)+abc$ by $a-b+c$

26. $a^2(b+c)+b^2(a-c)+c^2(a-b)+abc$ by $a+b+c$

27. $x^3-2ax^2+(a^2-ab-b^2)x+a^2b+ab^2$ by $x-a-b$

28. $a^3+b^3+c^3-3abc$ by $a+b+c$

29. $x^3+y^3-1+3xy$ by $x+y-1$

30. $x^3-8y^3-27z^3-18xyz$ by $x-2y-3z$

31. $x^3-y^3+z^3+3xyz$ by $x-y+z$

32. $8x^3-27y^3-z^3-18xyz$ by $4x^2+9y^2+z^2+6xy+2xz-3yz$

33. $a^2(b-c)+b^2(c-a)+c^2(a-b)$ by $a-b$

34. $(x^2-bx+cx)a-bc(x+a)+(x-b+c)x^2$ by $(x+a)(x-b)$

35. $c(ab-x^2)+(a-b)(x-c)x+x(x^2-ab)$ by $(x-b)(x-c)$

36. $a^3(b-c)+b^3(c-a)+c^3(a-b)$ by $ab+bc-ac-b^2$

37. $a^3(b^2-c^2)+b^3(c^2-a^2)+c^3(a^2-b^2)$
by $a^2b-bc^2-ac^2+a^2c$

38. $xy^3+2y^3z-xy^2z+xyz^2-x^3y-2yz^3+x^3z-xz^3$
by $y+z-x$

39. $b(x^3+a^3)+ax(x^2-a^2)+a^3(x+a)$ by $(a+b)(x+a)$

40. $(a-b)^2c^2+(a-b)c^3-(c^2-a^2)b^2+(c-a)b^3$
by $(a-b)c^2-(c-a)b^2$

[Arrange the given expressions according to descending powers of c]

41. $(ax+by)^3+(ax-by)^3-(ay-bx)^3+(ay+bx)^3$
by $(a+b)^2x^2-3ab(x^2-y^2)$

[Calcutta University Entrance Paper, 1888]

[Simplify the dividend and the divisor and then arrange the two expressions according to descending powers of x]

42. $x(1+y^2)(1+z^2)+y(1+z^2)(1+x^2)+z(1+x^2)(1+y^2)+4xyz$
by $1+xy+yz+zx$

[Calcutta University Entrance Paper, 1878]

[Arrange the expressions according to descending powers of x]

43. $(4x^3-3a^2x)^2+(4y^3-3a^2y)^2-a^6$ by $x^2+y^2-a^2$

[Bombay University Matriculation Paper, 1884]

Assuming the formula $a^m-a^n=a^{m-n}$ to be true for *all* values of m and n, show that

44. $a^0=1$ $[a^0=a^{m-m}=a^m-a^m=1]$

45. $a^{-n}=\frac{1}{a^n}$. $[a^{-n}=a^{0-n}=a^0-a^n=1-a^n]$

46. $x^{\frac{5}{2}}-x^{\frac{3}{2}}=x$ **47.** $x^{-\frac{3}{4}}-x^{-\frac{7}{4}}=x$

Divide

48. $a^{\frac{1}{2}}b^{\frac{2}{3}}$ by $a^{-1}b^{-\frac{1}{3}}$ **49.** $a^{-2}b^{\frac{1}{2}}c^{\frac{5}{2}}$ by $a^{-3}b^{\frac{3}{2}}c^2$

50. $15xyz$ by $-5x^{\frac{2}{3}}y^{\frac{3}{5}}z^{\frac{4}{5}}$ **51.** $9x^{\frac{4}{3}}-16y^{\frac{2}{3}}$ by $3x^{\frac{2}{3}}+4y^{\frac{1}{3}}$

52. $a+b$ by $a^{\frac{1}{3}}+b^{\frac{1}{3}}$

53. $a^3+a^{\frac{3}{2}}b^{\frac{3}{2}}+b^3$ by $a^{\frac{3}{2}}+a^{\frac{3}{4}}b^{\frac{3}{4}}+b^{\frac{3}{2}}$

54. $4x^{\frac{8}{3}}-37x^{\frac{4}{3}}y^{\frac{4}{3}}+9y^{\frac{8}{3}}$ by $2x^{\frac{4}{3}}+5x^{\frac{2}{3}}y^{\frac{2}{3}}-3y^{\frac{4}{3}}$

55. $a-b^2$ by $a^{\frac{1}{4}}-b^{\frac{1}{2}}$

56. $4a^{-10}+12a^{-\frac{15}{2}}b^{-\frac{3}{2}}+9a^{-5}b^{-3}-25b^{-6}$
by $2a^{-5}+3a^{-\frac{5}{2}}b^{-\frac{3}{2}}-5b^{-3}$.

57. $9x^{-\frac{5}{2}}-25x^{-\frac{5}{4}}y^{-\frac{3}{4}}+70x^{-\frac{5}{8}}y^{-\frac{9}{8}}-49y^{-\frac{3}{2}}$
by $3x^{-\frac{5}{4}}+5x^{-\frac{5}{8}}y^{-\frac{3}{8}}-7y^{-\frac{3}{4}}$.

58. a^3-b^2 by $a^{\frac{1}{2}}-b^{\frac{1}{3}}$

59. $x+y+z-3x^{\frac{1}{3}}y^{\frac{1}{3}}z^{\frac{1}{3}}$ by $x^{\frac{1}{3}}+y^{\frac{1}{3}}+z^{\frac{1}{3}}$

84. Inexact Division. It may so happen that the dividend is not exactly divisible by the divisior For instance, if in example 2, Art 83, the dividend were $16x^4+36x^2+6x+86$, the second remainder would be $36x^2+60x+86$, and hence the final remainder $6x+5$ As $6x+5$ cannot be divided by $4x^2+6x+9$, the division in this case would be incomplete and the result might be expressed as in Arithmetic, thus

$$\frac{16x^4+36x^2+6x+86}{4x^2+6x+9}=4x^2-6x+9+\frac{6x+5}{4x^2+6x+9}.$$

The right hand side is called the *complete quotient* The portion of the dividend which is thus left as a residue not divisible by the divisor is spoken of as *the remainder* in division, Hence, if D denote the dividend, d the divisior, Q the quotient, and R the *remainder* we have the following invarible relation betwen these symbols

$$D=d\times Q+R$$

85. Detached Co-efficients. If both the dividend and the divisor contain powers of the same algebraic quantity or be *homogeneous* expressions of same algebraic quantities, the labour of long division can be much saved by detaching the co-efficients and placing them in proper relative positions

The process is illustrated by the following examples.

Example 1. Divide $6x^4+13x^3+39x^2+37x+45$ by $3x^2+2x+9$

$$
\begin{array}{l}
3+2+9)\,6+13+39+37+45\,(2+3+5 \\
\qquad\quad\ \ \underline{6+\ 4+18\qquad\qquad} \\
\qquad\qquad\ +\ 9+21+37 \\
\qquad\qquad\ \underline{+\ 9+\ 6+27} \\
\qquad\qquad\qquad\quad 15+10+45 \\
\qquad\qquad\qquad\quad \underline{15+10+45}
\end{array}
$$

. the required quotient is $2x^2+3x+5$

By the ordinary method:

$$
\begin{array}{l}
3x^2+2x+9)\,6x^4+13x^3+39x^2+37x+45\,(2x^2+3x+5 \\
\qquad\qquad\quad \underline{6x^4+\ 4x^3+18x^2\qquad\qquad} \\
\qquad\qquad\qquad\quad 9x^3+21x^2+37x \\
\qquad\qquad\qquad\quad \underline{9x^3+\ 6x^2+27x} \\
\qquad\qquad\qquad\qquad\quad 15x^2+10x+45 \\
\qquad\qquad\qquad\qquad\quad \underline{15x^2+10x+45}
\end{array}
$$

The required quotient is $2x^2+3x+5$

Example 2. Divide x^3-27 by x^2+3x+9

N B If any power of x either in the dividend or in the divisor be absent, the term involving that power is to be supplied with a zero co-efficient

$$
\begin{array}{l}
1+3+9)\,1+0+0-27\,(1-3 \\
\qquad\quad\ \ \underline{1+3+9\qquad} \\
\qquad\qquad\ -3-9-27 \\
\qquad\qquad\ \underline{-3-9-27}
\end{array}
$$

the required quotient is $x-3$

EXERCISE 40.

Apply the method of detached co-efficients to find the quotient of the following

1. $2m^3-9m^2n+13mn^2-6n^3$ by $2m-3n$
2. $a^4-3a^3b+3ab^3-b^4$ by a^2-b^2
3. $2x^4-3x^3y-3xy^3-2y^4$ by x^2+y^2
4. $2a^4-36a^2x^2-16ax^3$ by $2a^2+8ax$
5. $3+2x+4x^2+5x^3-4x^4+2x^5$ by $1+2x^2$
6. $x^4-4x^2+12x-9$ by x^2+2x-3

7. $4a^4-9a^2b^2+24ab^3-16b^4$ by $2a^2-3ab+4b^2$

8. $a^4+4a^2x^2+16x^4$ by $a^2+2ax+4x^2$

9. a^4+4b^4 by $a^2+2ab+2b^2$

10. $2x^5-7x^4-2x^3+18x^2-3x-8$ by x^3-2x^2+1

11. x^4-81 by $x-3$ 12. a^5-32 by $a-2$

13. $3-9x+2x^2+5x^3-7x^4+2x^5$ by $1-3x+x^2$

14. $82x^2+40-45x^3+18x^4-67x$ by $6x^2+8-7x$

15. $64-x^6$ by $2-x$ 16. $1+x^6-2x^3$ by x^2+1-2x

17. $13ab^3+2a^2b^2+6a^4-a^3b+4b^4$ by $4ab+b^2+3a^2$

18. $a^3b-15b^4-8a^2b^2+a^4+19ab^3$ by a^2+3b^2-2ab

19. x^6-a^6 by $x^3-2x^2a+2xa^2-a^3$

20. $8a^2b^3+3b^5+a^5-9a^3b^2-2ab^4-a^4b$ by $2ab-3b^2+a^2$

21. $y^6+x^6-2x^3y^3$ by x^2+y^2-2xy

Find the complete quotient of ·

22. $\dfrac{x^2+11x+35}{x+5}$. 23. $\dfrac{x^3+\frac{1}{27}y^3}{x-\frac{1}{3}y}$.

24. Find the remainder when x^3+px^2+qx+r is divided by x^2+px+q

25. Divide $1+2x+4x^2$ by $3-x$, retaining four terms in the quotient.

86. A few important results.

The student already knows that

$$x^2-a^2=(x-a)(x+a)$$

and $$x^3-a^3=(x-a)(x^2+xa+a^2)$$

Hence, x^4-a^4 [which $=x^3(x-a)+a(x^3-a^3)$]

$$=(x-a)\{x^3+a(x^2+xa+a^2)\}$$
$$=(x-a)(x^3+x^2a+xa^2+a^3)$$

Hence, x^5-a^5 [which $=x^4(x-a)+a(x^4-a^4)$]

$$=(x-a)\{x^4+a(x^3+x^2a+xa^2+a^3)\}$$
$$=(x-a)(x^4+x^3a+x^2a^2+xa^3+a^4)$$

Similarly, it may be shown that $x-a$ is a factor of x^6-a^6, of x^7-a^7, of x^8-a^8 and so on, hence generally, $x-a$ is a factor of x^n-a^n where n is any whole number

We conclude therefore, that for *all* positive integral values of n, x^n-a^n is *divisible* by $x-a$

Again since, $x^n+a^n=(x^n-a^n)+2a^n$. of which x^n-a^n is divisible by $x-a$ and $2a^n$ is not, x^n+a^n is *not* divisible by $x-a$

Thus, when n is a positive integer,

$$\left.\begin{array}{ll} & x-a \textit{ always} \text{ divides } x^n-a^n, \\ \text{but} & \qquad\ \textit{never} \text{ divides } x^n+a^n \end{array}\right\} \qquad (A)$$

Cor. 1. $x+a$ divides x^n-a^n *only* when n is an *even* integer

For, when n is even, $(-a)^n=\ \ a^n$, † and $\therefore x^n-a^n=x^n-(-a)^n,$ when n is odd $(-a)^n=-a^n$, † and $\therefore x^n-a^n=x^n+(-a)^n$ also, $x+a=x-(-a)$

Now, from (A), we know that $x-(-a)$ divides $x^n-(-a)^n$, but not $x^n+(-a)^n$ Hence, $x+a$ divides x^n-a^n when n is even but not when n is odd $\therefore$ i e $x+a$ divides x^n-a^n *only* when n is an *even* integer

Cor. 2. $x+a$ divides x^n+a^n *only* when n is an *odd* integer

For, when n is odd, $(-a)^n=-a^n$, and $x^n+a^n=x^n-(-a)^n$ when n is even $(-a)^n=\ \ a^n$, and $x^n+a^n=x^n+(-a)^n,$ also, $x+a=x-(-a)$

Now, from (A), we know that $x-(-a)$ divides $x^n-(-a)^n$ but not $x^n+(-a)^n$ Hence, $x+a$ divides x^n+a^n when n is odd, but not when n is even i e, $x+a$ divides x^n+a^n *only* when n is an *odd* integer

Thus we have obtained the following results ‡

$$x-a \text{ divides } \left.\begin{array}{ll} x^n-a^n & \textit{always}, \\ x^n+a^n & \textit{never} \end{array}\right\}$$

$$x+a \text{ divides } \left.\begin{array}{l} x^n-a^n \ \textit{only} \text{ when } n \text{ is } \textit{even} \\ x^n+a^n \ \textit{only} \text{ when } n \text{ is } \textit{odd} \end{array}\right\}$$

EXERCISE 41.

Verify by actual division that the following expressions are divisible by $x+a$

1. x^3+a^3	**2.** x^4-a^4	**3.** x^5+a^5
4. x^6-a^6	**5.** x^7+a^7	**6.** x^8-a^8

† This follows from repeated application of the laws of signs in multiplication, thus $(-a)^2=a^2$, hence, $(-a)^3=(-a)\times(-a)^2=(-a)\times a^2=-a^3$, hence, $(-a)^4=(-a)\times(-a)^3=(-a)(-a^3)=a^4$, hence, $(-a)^5=(-a)(-a)^4=(-a)\times a^4=-a^5$, and so on That is, any power of $-a$ is positive or negative according as the index of that power is an even or an odd integer

‡ These results have been formally proved in Chapter XXIII

Verify by actual division that the following expressions are *not* divisible by $x+a$

7. x^3-a^3 **8.** x^4+a^4 **9.** x^5-a^5.

10. x^6+a^6 **11.** x^7-a^7 **12.** x^8+a^8.

Write down the quotient of

13. x^4-1 by $x-1$ **14.** x^4-y^4 by $x+y$.

15. x^5-1 by $x-1$ **16.** x^5+y^5 by $x+y$

17. x^6-1 by $x-1$ **18.** x^6-y^6 by $x+y$

19. x^7-1 by $x-1$ **20.** x^7+y^7 by $x+y$

CHAPTER XI

FORMULÆ AND THEIR GRAPHICAL REPRESENTATION

87. The different formulæ established in Chapter IV are stated below to facilitate any reference to them A complete knowledge of these special products is essential for performing many algebraical operations with neatness and accuracy It is therefore desired that the student should commit them to memory so that the necessity even for occasional references may be altogether done away with

(i) $(a+b)^2=a^2+2ab+b^2$

(ii) $(a-b)^2=a^2-2ab+b^2$

(iii) $(a+b)(a-b)=a^2-b^2$

(iv) $(a+b)^3=a^3+3a^2b+3ab^2+b^3=a^3+b^3+3ab(a+b)$

(v) $(a-b)^3=a^3-3a^2b+3ab^2-b^3=a^3-b^3-3ab(a-b)$

(vi) $a^3+b^3=(a+b)(a^2-ab+b^2)=(a+b)^3-3ab(a+b)$

(vii) $a^3-b^3=(a-b)(a^2+ab+b^2)=(a-b)^3+3ab(a-b)$

(viii) $(x+a)(x+b)=x^2+(a+b)x+ab$

(ix) $(x-a)(x+b)=x^2+(b-a)x-ab$

(x) $(x-a)(x-b)=x^2-(a+b)x+ab$

88. Application of Formulæ.

Example 1. Find the product of 999×999 and 9988×10012

We have $999 \times 999 = 999^2$

$$= (1000-1)^2$$
$$= 1000^2 - 2 \times 1000 \times 1 + 1^2 \quad \text{[Formula (ii)]}$$
$$= 1000000 - 2000 + 1$$
$$= 998001$$

Also, $9988 \times 10012 = 10012 \times 9988$

$$= (10000+12)(10000-12)$$
$$= 10000^2 - 12^2 \quad \text{[Formula (iii)]}$$
$$= 100000000 - 144$$
$$= 99999856$$

Example 2. Find the value of

$$2931^3 + 1069^3 + 12000 \times 2931 \times 1069$$

Putting a for 2931 and b for 1069, the given expression

$$= a^3 + b^3 + 12000ab$$
$$= a^3 + b^3 + 3ab(a+b)$$
$$[\text{since, } a+b = 2931 + 1069 = 4000]$$
$$= (a+b)^3 \quad \text{[Formula (iv)]}$$
$$= (4000)^3$$
$$= 4000 \times 4000 \times 4000$$
$$= 64000000000$$

Note *The student is referred to the examples worked out in Chapter IV for further illustrations*

89. Algebraic quantities expressed as the difference of two squares.

We have $a^2 + 2ab + b^2 = (a+b)^2$

and $a^2 - 2ab + b^2 = (a-b)^2$

Subtracting, $4ab = (a+b)^2 - (a-b)^2$

or, $ab = \frac{1}{4}(a+b)^2 - \frac{1}{4}(a-b)^2 = \left(\frac{a+b}{2}\right)^2 - \left(\frac{a-b}{2}\right)^2.$

Hence, the product of any two factors

= square of ($\frac{1}{2} \times$ sum of the factors)

− square of ($\frac{1}{2} \times$ the difference of the factors)

Example 1. Express $(x+y+2z)(x+y)$ as the difference of two squares

$$(x+y+2z)(x+y)$$

$$=\left\{\frac{(x+y+2z)+(x+y)}{2}\right\}^2-\left\{\frac{(x+y+2z)-(x+y)}{2}\right\}^2$$

$$=\left(\frac{2x+2y+2z}{2}\right)^2-\left(\frac{x+y+2z-x-y}{2}\right)^2$$

$$=(x+y+z)^2-z^2$$

Example 2. Express $(x+1)(2x+3)(x+5)$ as the difference of two squares

The expression

$$=\{(x+1)(2x+3)\}(x+5)$$

$$=(2x^2+5x+3)(x+5)$$

$$=\left\{\frac{(2x^2+5x+3)+(x+5)}{2}\right\}^2-\left\{\frac{(2x^2+5x+3)-(x+5)}{2}\right\}^2$$

$$=(x^2+3x+4)^2-(x^2+2x-1)^2$$

Example 3. Express $(x+a)(x+2a)(x+3a)(x+4a)$ as the difference of two squares

The given expression

$$=\{(x+a)(x+4a)\}\{(x+2a)(x+3a)\}$$

$$=(x^2+5ax+4a^2)(x^2+5ax+6a^2)$$

$$=\left\{\frac{(x^2+5ax+4a^2)+(x^2+5ax+6a^2)}{2}\right\}^2$$

$$-\left\{\frac{(x^2+5ax+6a^2)-(x^2+5ax+4a^2)}{2}\right\}^2$$

$$=(x^2+5ax+5a^2)^2-(a^2)^2$$

Example 4. Express $(x+2a)(x+4a)(x+6a)(x+8a)+7a^4$ as the difference of two squares

The given expression

$$=\{(x+2a)(x+8a)\}\{(x+4a)(x+6a)\}+7a^4$$

$$=(x^2+10ax+16a^2)(x^2+10ax+24a^2)+7a^4$$

$$=\left\{\frac{(x^2+10ax+16a^2)+(x^2+10ax+24a^2)}{2}\right\}^2$$

$$-\left\{\frac{(x^2+10ax+24a^2)-(x^2+10ax+16a^2)}{2}\right\}^2+7a^4$$
$$=(x^2+10ax+20a^2)^2-(4a^2)^2+7a^4$$
$$=(x^2+10ax+20a^2)^2-16a^4+7a^4$$
$$=(x^2+10ax+20a^2)^2-(3a^2)^2$$

EXERCISE 42.

(The following examples are to be worked out with the help of the formulae of Art 87)

Find the squares of the following

1. $5x+9y$. **2.** $16a-13b$ **3.** $x+100$ **4.** $y+500$
5. $a+999$ **6.** $y+10001$ **7.** 988 **8.** 1012
9. 100 5 **10.** 99 6

Find the cubes of the following

11. $2x+5$ **12.** 105 **13.** 99 5 **14.** 800 6

15. Show that $(a+b)^2+(a-b)^2=2(a^2+b^2)$

Hence, find the value of a^2+b^2 when

(i) $a=5004$, $b=4996$, (ii) $a=1012$ $b=988$

16. Show that $(a+b)^2-(a-b)^2=4ab$

Hence express the following as the difference of two squares

(i) $4(x+2y)(2x+y)$ (ii) $(6x+10y)(4x+6y)$,
(iii) $(x+98)(x+102)$, (iv) 505×495,
(v) $(2x+100\ 4)(2x+99\ 6)$

Find the following products:

17. $(a+x)(a-x)(a^2+x^2)$ **18.** $(2a+3)(2a-3)(4a^2+9)$
19. $(a^2-ab+b^2)(a^2+ab+b^2)(a^4-a^2b^2+b^4)$
20. $98\times102\times10004$ **21.** $96\times104\times10016$
22. $(2a+x)(4a^2+4ax+x^2)$
23. $(a-2)(a+2)(a^2+4a+4)(a^2-4a+4)$
24. $(x+4)(x^2-4x+16)$ **25.** $(2y-3)(4y^2+6y+9)$
26. $(x+2)(x^2+2x+4)(x-2)(x^2-2x+4)$
27. $(2x+105)(2x+15)$ **28.** $(6x-25)(6x+43)$
29. $(6x-25)(6x-43)$

Simplify the following

30. $(2a+x+y)^2+2(2a+x+y)(8a-x-y)+(8a-x-y)^2$

31. $(17a+20x+19y)^2-2(19x+18y+17a)(20x+19y+17a)$
$+(19x+18y+17a)^2$

32. $(16a+x+y)^3+(4a-x-y)^3+3(16a+x+y)^2(4a-x-y)$
$+3(16a+x+y)(4a-x-y)^2$

33. $(121a+x+y)^3-(116a+x+y)^3$
$-15a(121a+x+y)(116a+x+y)$

34. $(5a-8x)^3+(6a+8x)^3+33a(5a-8x)(6a+8x)$

35. $(2x+3y-16z)^3+3(3x-3y+16z)^2(2x+3y-16z)$
$+(3x-3y+16z)^3+3(3x-3y+16z)(2x+3y-16z)^2-120x^3$

Resolve into factors

36. x^2+5x+6

37. $5y^2+65y+200$

38. a^4+4b^4

39. $(x+y)^2+15(x+y)+36$

40. $(5a+8b+2)^2-(4a+6)^2$

41. $8x^3+125y^3$

42. $(8a+13x)^3-64$

43. $(15a+3b)^2-4$

44. $5x^3-5x^2y-30xy^2$

Find the value of

45. $(16a+2b)^2-2(13a+2b)(16a+2b)+(13a+2b)^2$,
when $a=5$ and $b=7891$

46. $(91x+5y)^3-3(91x+5y)^2(87x+5y)$
$+3(91x+5y)(87x+5y)^2-(87x+5y)^3$, when $x=2$ and $y=83$

47. $(589963)^2-2\times589963\times589863+(589863)^2$

48. $90{\cdot}002\times89{\cdot}998$

49. 9238^2-9233^2

50. $49856\times49856\times49856-3\times49856\times49855$
$-49855\times49855\times49855$

51. Factorize $(x+2)(2x+1)(5x+2)-3x^4$ by expressing it as the difference of two squares

52. Show that $(ax+b)(bx+a)\{abx^2-(a^2+b^2)x+ab\}$ can be expressed as the difference of two squares

53. Express $(5x+1)(2x+5)(3x+5)(4x+3)$ as the difference of two squares

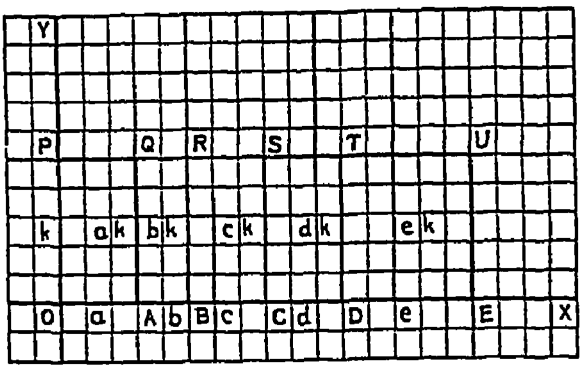
54. Express $(7x+3a)(7x+5a)(7x+9a)(7x+11a)+61a^4$ as the sum of two squares

90. Graphical Representation of Algebraic Formulæ. Some of the formulæ are illustrated below by their geometrical representations on squared paper

(1) To demonstrate graphically, the identity

$$(a+b+c+d+e)k=ak+bk+ck+dk+ek.$$

Let OX and OY be the co-ordinate axes, O being the origin



Let A, B, C, D, E be the points on OX. such that $OA=a$ $AB=b$, $BC=c$, $CD=d$ and $DE=e$ Also, let P be a point on OY, such that $OP=k$ Complete the rectangle $OPUE$ Through A, B, C, D E draw AQ, BR. CS, DT, EU parallels to OP so as to meet PU in Q R S, T, U respectively, so that the figures $OPQA$ $AQRB$, $BRSC$, $CSTD$ $DTUE$ are each a rectangle

Now, rect PE=rect PA+rect QB+rect RC+rect SD +rect TE (1)

But, rect $PE=OE\ OP=(OA+AB+BC+CD+DE)\ OP$
$=(a+b+c+d+e)\,k.$

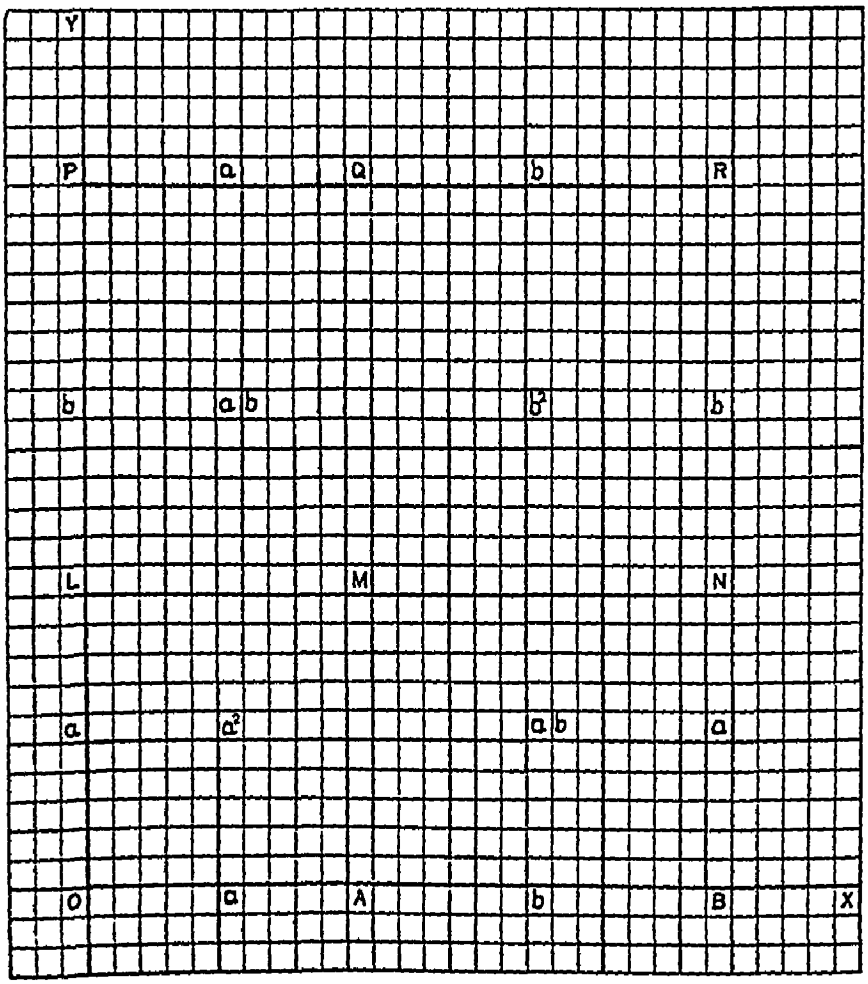
and rect $PA=OA\ OP$
$=ak\,;$

rect $QB=AB\ AQ=AB\ OP$
$=bk\,,$

rect $RC = BC\,BR = BC\,OP$
$= ck$,
rect $SD = CD\,CS = CD\,OP$
$= dk$,
rect $TE = DE\,DT = DE\,OP$
$= ek$,
from (1),
$$(a+b+c+d+e)k = ak+bk+ck+dk+ek$$

(2) To demonstrate graphically, the identity
$$(a+b)^2 = a^2 + 2ab + b^2.$$

Let OX and OY be the co-ordinate axes, and O be the origin



Let A and B be two points taken on OX, such that $OA=a$ and $AB=b$, also, let L and P be two points on OY such that $OL=a$ and $LP=b$ Then, $OB=OP=a+b$ Complete the square $OPRB$ Let AQ be drawn through A parallel to OY to meet PR in Q, also let LMN be drawn through L parallel to OX to meet AQ in M and BR in N

$$\text{Then, fig } OR = \text{fig } OM + \text{fig } AN + \text{fig. } LQ + \text{fig } MR \qquad (1)$$

$$\begin{aligned}
\text{Now, fig } OR &= OB\,OP \\
&= OB\,OB \qquad [\quad OP=OB] \\
&= OB^2 = (a+b)^2, \\
\text{fig } OM &= OA\,OL = OA\,OA \\
&= a^2, \\
\text{fig } AN &= AM\,AB = OL\,AB \\
&= ab, \\
\text{fig } LQ &= LM\,LP \\
&= PQ\,LP = ab, \\
\text{fig } MR &= MN\,MQ = QR\,LP \\
&= b\,b = b^2
\end{aligned}$$

From (1)

$$\begin{aligned}
(a+b)^2 &= a^2+ab+ab+b^2 \\
&= a^2+2ab+b^2
\end{aligned}$$

(3) To demonstrate graphically, the identity

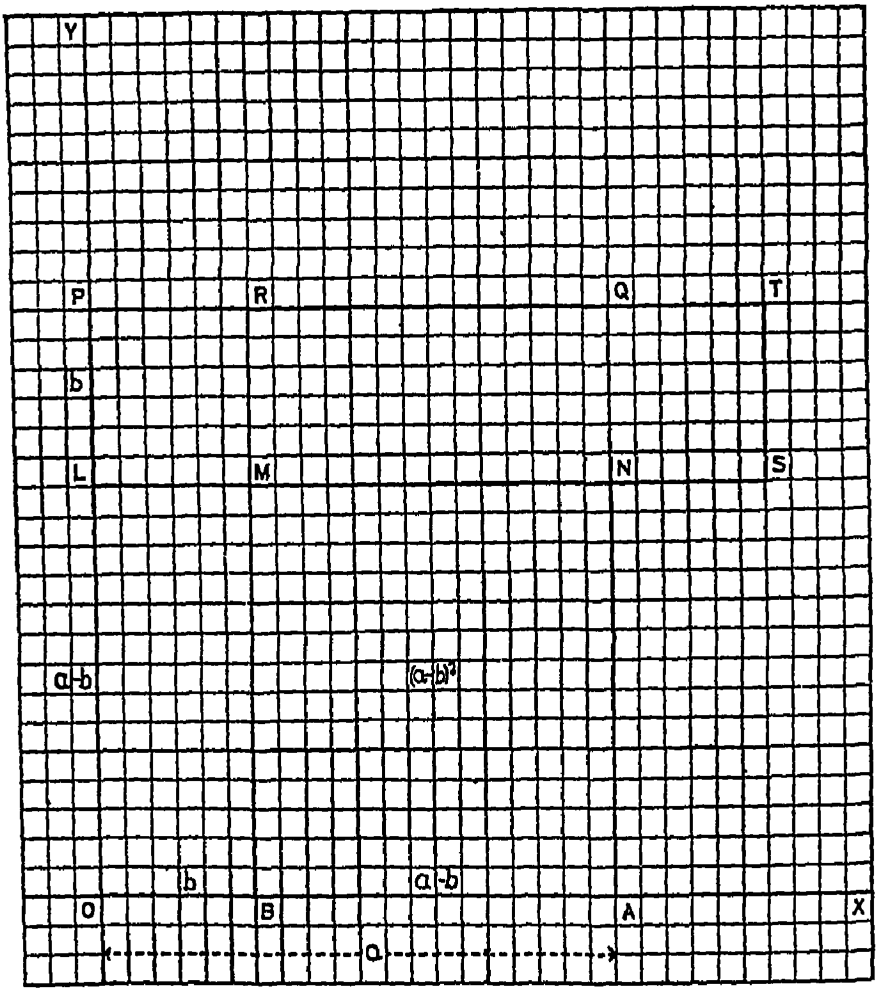
$$(a-b)^2 = a^2 - 2ab + b^2$$

Let OX and OY be the co-ordinate axes, and O, the origin

Take two points A and B, on OX such that $OA=a$ and $OB=b$ Complete the square $OPQA$, on OA Through B, draw BR parallel to OY to meet PQ in R, cut off a length PL from PO, equal to b Through L, draw LMN parallel to OX to meet BR and AQ in M and N respectively Produce PQ to T, making $QT=PR$ $(=b)$ Complete the square $QTSN$, on QT

Since, $OA = a$ and $OB = b$,

$\therefore \quad BA = a - b$



Also, since, $OP = OA = a$

and $PL = b$

$\therefore \quad OL = a - b$

$\therefore \quad AB = OL$

Now, fig BN = fig OQ + fig NT − fig OR − fig RS (1)

But, fig $BN = BA\,BM = BA\,OL$

$= BA\,BA = BA^2$

$= (a-b)^2$,

fig $OQ = OA\,OP = OA\,OA$

$= OA^2 = a^2$

fig NT = sq on QT
= sq on PR
= b^2,

fig $OR = OP \cdot OB = OA \cdot OB$
= ab,

fig RS = fig RN + fig QS
= fig RN + fig PM
= fig PN [∵ fig QS = fig PM, each
= $PQ \cdot PL$ being equal to b^2]
= ab

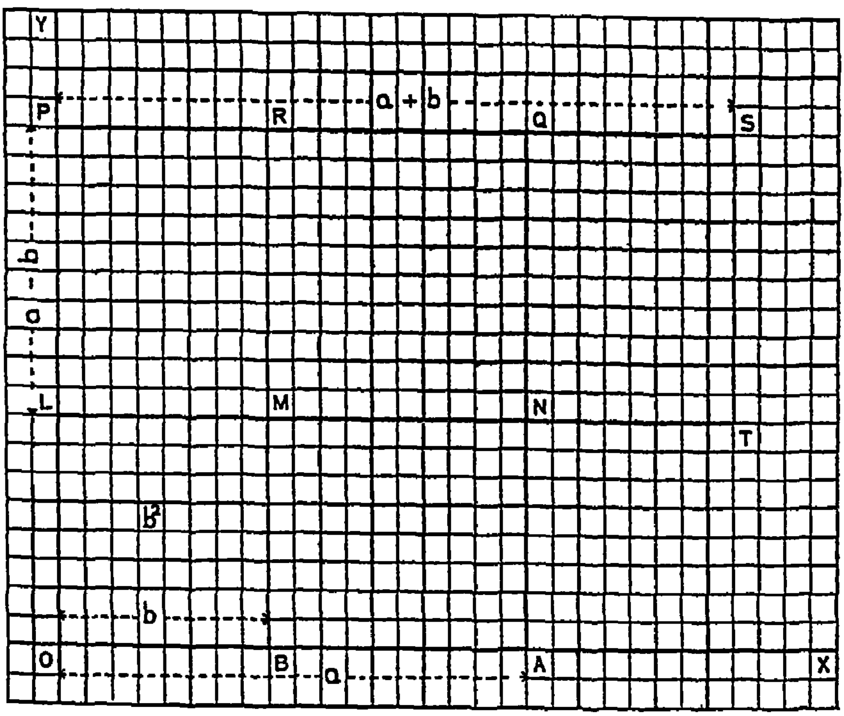
From (1),

$$(a-b)^2 = a^2 + b^2 - ab - ab, \text{ i e }, = a^2 + b^2 - 2ab$$

(4) To demonstrate graphically, the identity

$$a^2 - b^2 = (a-b)(a+b).$$

Let OX and OY be the co-ordinate axes, and O the origin



Take two points A and B on OX such that $OA=a$ and $OB=b$, also, take two points, P and L, on OY such that $OP=a$ and $OL=b$

Complete the squares $OPQA$ and $OLMB$ Produce BM to meet PQ in R and LM to meet AQ in N, also produce MN to T, making $NT=NA(=b)$ and complete the rectangle $NTSQ$

Thus, rect BN = rect QT

also, $PL=OP-OL=a-b$

and $AB=OA-OB=a-b$

$PL=AB$

Now fig PA − fig BL

= fig PN + fig BN

= fig PN + fig QT

= fig PT (1)

But fig PA = sq on OA

$=a^2$,

fig BL = sq on OB

$=b^2$,

fig $PT=PS\ PL$

$=(PQ+QS)\ PL$

$=(PQ+NT)\ PL$

$=(a+b)(a-b)$

From (1),

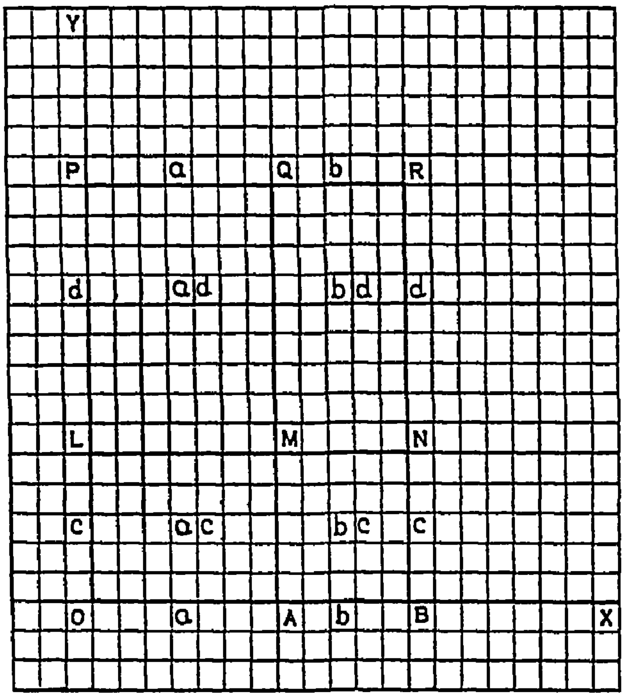
$$a^2-b^2=(a-b)(a+b)$$

(5) To demonstrate graphically, the identity

$$(a+b)(c+d)=ac+bc+ad+bd.$$

Let OX and OY be the co-ordinate axes, and O the origin

On OX take two points, A and B, making $OA=a$ and $AB=b$, also, on OY take two points, P and L, making $OL=c$ and $LP=d$



Complete the rectangles $OPRB$ and $OLNB$

Through A draw AMQ parallel to OY to meet LN in M and PR in Q

Now fig OR = fig OM + fig AN + fig LQ + fig MR (1)

But, fig $OR = OB\ OP$
$= (OA + AB)(OL + LP)$
$= (a+b)(c+d)$

fig $OM = OA\ OL = ac$

fig. $AN = AB\ AM$
$= AB\ OL = bc$,

fig $LQ = PQ\ PL$
$= OA\ PL = ad$

fig $MR = QR\ QM$
$= AB\ PL = bd$

From (1),

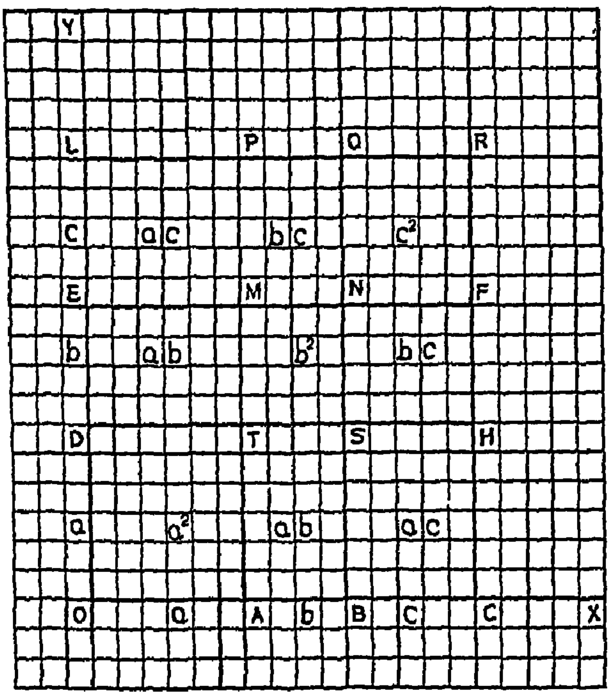
$$(a+b)(c+d) = ac + bc + ad + bd$$

(6) To demonstrate graphically, the identity

$$(a+b+c)^2=a^2+b^2+c^2+2ab+2bc+2ac.$$

Let OX and OY be two perpendicular straight lines, through O

Take three points A, B and C on OX such that $OA=a$, $AB=b$, $BC=c$



Complete the square $OCRL$ on OC, so that

$$OL=OC=OA+AB+BC=a+b+c$$

Let D and E be points on OL such that

$$OD=a \text{ and } DE=b, \text{ whence } EL=c$$

Through A and B, draw AP and BQ parallels to OY to meet LR in P and Q respectively, also through D and E draw $DTSH$ and $EMNF$ parallels to OX to meet AP, BQ. CR in points T, S, H and M N, F respectively

Then, fig $OR=$fig $OT+$fig $TN+$fig NR
+fig $DM+$fig $AS+$fig $PN+$fig NH
+fig $EP+$fig BH . (1)

Now. fig $DM = DT\ DE = OA\ AB = ab$

and fig $AS = AT\ AB = OD\ AB = ab$

Similarly, fig $NP =$ fig $NH = bc$

and fig $EP =$ fig $BH = ac$

Also, fig $OR =$ sq on $OC = OC^2$

$$= (OA + AB + BC)^2 = (a+b+c)^2$$

fig $OT = OA\ OD = OA\ OA = OA^2 = a^2$

fig $TN = TM\ TS = AB\ DE = AB^2 = b^2$

fig $NR = NQ\ NF = EL\ BC = BC^2 = a^2$

From (1),

$$(a+b+c)^2 = a^2 + b^2 + c^2 + ab + ab + bc + bc + ac + ac$$

i e, $$= a^2 + b^2 + c^2 + 2ab + 2bc + 2ac$$

EXERCISE 43.

Find, graphically, the value of .

1. (i) $(5+6) \times 11$ (ii) 7^2 (iii) $(\frac{5}{2} - \frac{1}{2})^2$

2. Verify graphically

(i) $9^2 - 7^2 = 32$ (ii) $(7+3)^2 = 100$

(iii) $(3+5) \times 2 = 3 \times 2 + 5 \times 2$

(iv) $(x+a)(x+b) = x^2 + (a+b)x + ab$

(v) $(x-a)(x-b) = x^2 - (a+b)x + ab$

(vi) $(x-a)(x+b) = x^2 - ax + bx - ab$

3. Calculate graphically, the area of a square described on a straight line whose length is equal to twelve feet

4. Find, graphically, the area of a room, 5 ft long and 3 ft broad

5. A rectangular garden of length 9 yards and breadth 3 yards has got a path of uniform breadth surrounding it If the breadth of the path be one yard, find, graphically, the total area of the garden and the path together

6. In a square plot of land of side 10 yards, a square pond of length four yards is dug Find graphically, the area of the remaining portion of the land

7. Find, graphically, the area of a rectangular plot of land whose length is 50 yards, and is five times its breadth

8. A rectangular court-yard of length 10 yards and breadth 5 yards is to be paved with square stones If the side of the stone be one yard find, graphically, the number of stones necessary for the purpose

9. A square garden of side 20 yards has within it a walk of uniform breadth equal to one yard running round it Find, graphically the area of the path

10. A rectangular court of length 20 yards and breadth 10 yards has two paths, each of breadth one yard joining the middle points of the opposite sides, and *symmetrically* situated about the lines joining those middle points, find, graphically, the area of that portion of the court which is not covered by the path

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CHAPTER XII

SIMPLE FACTORS

91. Definitions. When an expression is the product of two or more others, each of these latter is called a **factor** of the former

An expression is said to be *resolved into factors* when those expressions of which it is the product are found

[A few simple cases of resolution into factors have already been incidentally treated in the Chapter on *Formula and their Application* These cases, however, will not be altogether passed over in the following articles as the present chapter is intended for a more systematic treatment of the subject]

Note *In this chapter we shall confine our attention to **rational** and **integral** expressions only (i e expressions free from radical signs and in which no letter occurs in the denominator of any term), and by the factors of an expression will be meant the **rational** and **integral** expressions of which it is the product*

92. Simple Cases. Any expression, *all the terms of which have got a common factor* may, on inspection, be at once resolved into two factors, one of which is simple and the other compound, thus

(1) $a^2x+ax^2=ax(a+x)$.

(2) $2a^3b^2-3a^2b^3=a^2b^2(2a-3b)$

(3) $24x^4a^3-40x^3a^4+56x^2a^5=8x^2a^3(3x^2-5xa+7a^2)$

EXERCISE 44.

Resolve into factors

1. $ab+ac$. **2.** $a^2b^3+a^3b^2$

3. $x^3y^4-2x^4y^3$. **4.** $2x^2yz+4xy^2z-6xyz^2$

5. $4a^5b-6a^4b^2-8a^3b^3$ **6.** $ax^2y-5a^2x^3y^2+3ax^3$

7. $3x^4y^3z^2-12x^2y^4z^3+21x^8y^2z^4$

8. $28a^8b^5-42a^5b^8$ **9.** $72x^{10}y^8+108x^8y^{10}$

10. $39a^5b^7c^7-65b^5c^7a^7-91c^5a^7b^7$

93. Expressions of the form a^2-b^2.

The method of resolving into factors an expression of this form has already been treated in Art 56, Note A few more examples are added here for the exercise of the student

EXERCISE 45.

Resolve into factors

1. $9a^2-16b^2$ **2.** $4a^3-25ax^2$ **3.** $36x^4-1$

4. $16x^4-1$ **5.** $16x^5-9x$ **6.** $16x^5-81x$

7. $1-16a^4$ **8.** x^2-81x^6 **9.** $36-x^4a^2$

10. $64a^4-49x^6$ **11.** $121-m^6$ **12.** $49x^6a^{10}-81$

13. $a^2b^2-25c^2d^2$ **14.** $81x^{12}-64a^{10}$. **15.** $p^2q^4-100p^2$

16. $144x^7-25x^3a^4$ **17.** $192a^9-243a^5x^4$

18. $98a^3x^5-128ax$ **19.** $324x^{17}a^9-484x^5a^3$

20. $245m^{23}n^{13}-605m^{15}n^7$ **21.** $(a+3b)^2-25c^2$

22. $a^2-(3b-5c)^2$ **23.** $(x+y)^2-(x-y)^2$

24. $(3a+2x)^2-(2a+x)^2$ **25.** $4(a-b)^2-9(c-d)^2$

26. $49x^2-(5y-3z)^2$ **27.** $(8x+5)^2-(2x-7)^2$

28. $(a+b-c)^2-(a-b+c)^2$

29. $(2a-3b+4c)^2-(a+4b-5c)^2$

30. $64(a+3x-4y)^2-9(2a-x+3y)^2$

31. $(4x^2-5a^2)^2-(5x^2-4a^2)^2$

32. $(5a^2-3a+7)^2-(5a^2-3a-7)^2$

94. Expressions which by mere inspection can be put into the form a^2-b^2. The following examples are intended for illustration

Example 1. Resolve into factors $a^4+a^2b^2+b^4$

$$\begin{aligned} a^4+a^2b^2+b^4 &= (a^4+2a^2b^2+b^4)-a^2b^2 \\ &= (a^2+b^2)^2-(ab)^2 \\ &= \{(a^2+b^2)+ab\}\{(a^2+b^2)-ab\} \\ &= (a^2+ab+b^2)(a^2-ab+b^2) \end{aligned}$$

Example 2. Resolve into factors x^4+4

$$\begin{aligned} x^4+4 &= (x^4+4x^2+4)-4x^2 \\ &= (x^2+2)^2-(2x)^2 \\ &= \{(x^2+2)+2x\}\{(x^2+2)-2x\} \\ &= (x^2+2x+2)(x^2-2x+2) \end{aligned}$$

Example 3. Resolve into factors x^4-6x^2+1

$$\begin{aligned} x^4-6x^2+1 &= (x^4-2x^2+1)-4x^2 \\ &= (x^2-1)^2-(2x)^2 \\ &= \{(x^2-1)+2x\}\{(x^2-1)-2x\} \\ &= (x^2+2x-1)(x^2-2x-1) \end{aligned}$$

Example 4. Resolve into factors $a^2-b^2+2bc-c^2$

$$\begin{aligned} a^2-b^2+2bc-c^2 &= a^2-(b^2-2bc+c^2) \\ &= a^2-(b-c)^2 \\ &= \{a+(b-c)\}\{a-(b-c)\} \\ &= (a+b-c)(a-b+c) \end{aligned}$$

Example 5. Resolve into factors $2(ab+cd)-a^2-b^2+c^2+d^2$

The given expression $=(c^2+2cd+d^2)-(a^2-2ab+b^2)$

$=(c+d)^2-(a-b)^2$

$=\{(c+d)+(a-b)\}\{(c+d)-(a-b)\}$

$=(c+d+a-b)(c+d-a+b)$

EXERCISE 46.

Resolve into factors

1. x^4+x^2+1 **2.** $x^8+x^4+1.$ **3.** $a^4+a^2x^2+x^4$

4. $a^8+a^4x^4+x^8.$ [C U Entrance Paper, 1887.]

5. x^4+64 **6.** $4x^4+81$ **7.** $9x^4+36$

8. a^4+2a^2+9 **9.** x^4-7x^2+9 **10.** $4x^4+8x^2+9$

11. $4x^4-16x^2+9$ **12.** $4x^4+3x^2+9$

13. $4a^4-37a^2+9$ **14.** $4a^4+625.$

15. $9x^4+23x^2+16.$ **16.** $9a^4-25a^2+16$

17. $9x^4-33x^2+16$ **18.** $9a^4-a^2+16$

19. $16x^4+4x^2a^2+25a^4$ **20.** $9a^4-19a^2x^2+25x^4$

21. x^4+8x^2+144 **22.** $a^4-35a^2b^2+25b^4$

23. $36a^4-16a^2b^2+b^4$ **24.** $49m^4+16n^4-60m^2n^2$

25. $64a^4+81x^4$ **26.** $4x^4+(7a)^4$

27. $x^2-y^2+2yz-z^2$ **28.** $4a^2-b^2-9c^2+6bc$

29. $9x^2-4y^2+12yz-9z^2$ **30.** $a^2-4b^2-25c^2+20bc$

31. $30xz+16y^2-9x^2-25z^2$

32. $a^2+4b^2-9c^2-4d^2-4ab+12cd$

33. $(x^2-2xy)-(z^2-2yz)$

34. $4x^2-1+9a^2-25b^2+12xa-10b$

35. $9x^2-4y^2-49z^2-30x+28yz+25$

36. $16a^2-16c^2-9b^2-24a+24bc+9$

37. $49y^2+20z+x^2-14xy-25z^2-4$

38. $16x^2+42by-9y^2+40xa-49b^2+25a^2$

39. $49x^2-1+16y^2-64z^2+16z-56xy$

40. $a^2-b^2-c^2+d^2-2(ad-bc)$

95. Expressions of the form a^3+b^3 or a^3-b^3.

The resolution of such expressions into factors has already been considered in Articles 59 and 60, Notes A few cases, however, of a little more complicated character may, with advantage, be added here

Example 1. Resolve into factors a^9+x^9

Since $a^3+b^3=(a+b)(a^2-ab+b^2)$

we have
$$\begin{aligned} a^9+x^9 &= (a^3)^3+(x^3)^3 \\ &= (a^3+x^3)\{(a^3)^2-(a^3)(x^3)+(x^3)^2\} \\ &= (a^3+x^3)(a^6-a^3x^3+x^6) \\ &= (a+x)(a^2-ax+x^2)(a^6-a^3x^3+x^6) \end{aligned}$$

Example 2. Resolve into factors a^9-x^9

Since $a^3-b^3=(a-b)(a^2+ab+b^2)$

we have
$$\begin{aligned} a^9-x^9 &= (a^3)^3-(x^3)^3 \\ &= (a^3-x^3)\{(a^3)^2+(a^3)(x^3)+(x^3)^2\} \\ &= (a^3-x^3)(a^6+a^3x^3+x^6) \\ &= (a-x)(a^2+ax+x^2)(a^6+a^3x^3+x^6) \end{aligned}$$

Example 3. Resolve into factors $64x^7-xa^6$

$$\begin{aligned} 64x^7-xa^6 &= x(64x^6-a^6) \\ &= x\{(8x^3)^2-(a^3)^2\} \\ &= x(8x^3+a^3)(8x^3-a^3) \\ &= x\{(2x)^3+a^3\}\{(2x)^3-a^3\} \\ &= x\{(2x+a)(4x^2-2xa+a^2)\}\{(2x-a)(4x^2+2xa+a^2)\} \\ &= x(2x+a)(2x-a)(4x^2-2xa+a^2)(4x^2+2xa+a^2) \end{aligned}$$

Otherwise

$$\begin{aligned} 64x^7-xa^6 &= x(64x^6-a^6) \\ &= x\{(4x^2)^3-(a^2)^3\} \\ &= x(4x^2-a^2)(16x^4+4x^2a^2+a^4) \\ &= x(2x+a)(2x-a)\{(16x^4+8x^2a^2+a^4)-4x^2a^2\} \\ &= x(2x+a)(2x-a)\{(4x^2+a^2)^2-(2xa)^2\} \\ &= x(2x+a)(2x-a)(\overline{4x^2+a^2}+2xa)(\overline{4x^2+a^2}-2xa) \\ &= x(2x+a)(2x-a)(4x^2+2xa+a^2)(4x^2-2xa+a^2) \end{aligned}$$

Note *Although the resolution can be effected in either of the two ways shown above, it is generally found convenient to adopt the first method*

EXERCISE 47.

Resolve into factors

1. a^3-8b^3 **2.** a^4-27ax^3 **3.** $512x^9+1$

4. a^9-512b^9. **5.** $27a^6+125x^6$ **6.** m^6-n^6

7. $343x^3+512y^3$ [C U Entrance Paper, 1882]

8. $64x^{12}-1$ **9.** a^6-64x^{12} **10.** $125x^9-216a^9$.

11. $64a^{13}b+343ab^{13}$ **12.** $729x^{20}y^2-64x^2y^{20}$

13. $(a^2+b^2)^3+8a^3b^3$ **14.** $(2x^2-3y^2)^3+y^6$

15. $(2a^3-b^3)^3-b^9$

96. Expressions of the form x^2+px+q resolved into factors by inspection.

From the relation $x^2+(a+b)x+ab=(x+a)(x+b)$, it is clear that to resolve an expression of the form x^2+px+q into two factors we have to find two quantities a and b such that $a+b=p$ and $ab=q$ This can be done by inspection whenever a and b are rational and integral The student can very well refer himself to the examples worked out after Art 60, for a clearer comprehension of such cases

Example 1. Resolve into factors $x^2+17x+30$

We have to find two numbers whose sum $=17$, and product $=30$

Pairs of numbers whose products is 30 are (i) 1 and 30, (ii) 2 and 15, (iii) 3 and 10, (iv) 5 and 6 Out of these four pairs we must pick out that, of which the sum is 17, the second pair, therefore, is the one sought

Thus 2 and 15 are the numbers required

Hence $x^2+17x+30=(x+2)(x+15)$

Example 2. Resolve into factors $x^2-11x+24$

We must find two numbers whose product $=+24$, and sum $=-11$ Clearly then the two numbers must be *both* negative

The pairs of negative numbers whose product is 24 are (i) -1 and -24, (ii) -2 and -12 (iii) -3 and -8,

(iv) -4 and -6 Out of these four pairs we must pick out that of which the sum is -11, the third pair therefore is the one sought

Thus, the required numbers are -3 and -8

Hence, $x^2-11x+24=(x-3)(x-8)$

Example 3. Resolve into factors $x^2+6x-40$

We must find two numbers whose product $=-40$, and sum $=+6$

The pairs of numbers whose product is -40 are: (i) 1 and -40, (ii) -1 and 40, (iii) 2 and -20, (iv) -2 and 20, (v) 4 and -10, (vi) -4 and 10, (vii) 5 and -8, (viii) -5 and 8 Out of these 8 pairs we must pick out that of which the sum is $+6$, the sixth pair therefore is the one sought

Thus, the required numbers are -4 and 10

Hence $x^2+6x-40=(x-4)(x+10)$

Note *From the fact that the sum of the two numbers is positive it is clear that the positive number must be* ***numerically*** *greater than the negative Hence, we might at once reject the first, third, fifth and seventh of the above pairs*

Example 4. Resolve into factors $x^2-5x-36$

We have to find two numbers whose product $=-36$, and sum $=-5$ Clearly then the numbers must have different signs and the negative number must be numerically greater than the positive one

Hence, the only admissible pairs of numbers whose product is -36 are (i) 1 and -36, (ii) 2 and -18, (iii) 3 and -12, (iv) 4 and -9 Out of these 4 pairs we must pick out that of which the sum is -5, the last pair therefore is the one sought

Thus, the required numbers are 4 and -9

Hence, $x^2-5x-36=(x+4)(x-9)$

Example 5. Resolve into factors $a^2+7ab+12b^2$

The factors will evidently be $a+pb$ and $a+qb$ where p and q are such that $p+q=7$, and $pq=12$

Arguing as before it is easy to see that 3 and 4 are the numbers whose sum is 7, and product 12.

Hence, $a^2+7ab+12b^2=(a+3b)(a+4b)$

Example 6. Resolve into factors $m^2-12mn+20n^2$

We have to find two numbers whose sum $=-12$, and product $=20$

Arguing in the usual way we find that -10 and -2 are the required numbers

Hence, $m^2-12mn+20n^2=(m-10n)(m-2n)$

Example 7. Resolve into factors a^4-a^2-12

Putting x for a^2, the given expression becomes x^2-x-12, and it is easy to see that $x^2-x-12=(x-4)(x+3)$

Hence, $a^4-a^2-12=(a^2-4)(a^2+3)=(a+2)(a-2)(a^2+3)$

Example 8. Resolve into factors $(x^2+2x)^2-3(x^2+2x)-18$

Putting a for x^2+2x, the given expression becomes $a^2-3a-18$, and it is easy to see that

$$a^2-3a-18=(a-6)(a+3)$$

Hence, the given expression $=\{(x^2+2x)-6\}\{(x^2+2x)+3\}$
$$=(x^2+2x-6)(x^2+2x+3)$$

Example 9. Resolve into factors

$$(5a+b)^2+(5a+b)(a+2b)-20(a+2b)^2$$

Putting x for $5a+b$ and y for $a+2b$, the given expression becomes $x^2+xy-20y^2$

Now it can be easily seen that

$$x^2+xy-20y^2=(x+5y)(x-4y)$$

Hence, the given expression

$$=\{(5a+b)+5(a+2b)\}\{(5a+b)-4(a+2b)\}$$
$$=(10a+11b)(a-7b)$$

Example 10. Resolve into factors $8x^2+2x-3$

First Method : Find the product of *the co-efficient of* x^2 and *the term independent of* x

In the present case, the *product* $=8\times(-3)=-24$

Now, resolve -24 into two factors whose *sum* = the coefficient of x, *i e* 2

By trial, the factors are 6 and -4

Thus the given exp $=8x^2+6x-4x-3$
$$=2x(4x+3)-(4x+3)=(4x+3)(2x-1)$$

Second Method : The given expression $=8x^2+2x-3$

$=\frac{1}{8}(8\times 8x^2+2\times 8x-3\times 8)$

$=\frac{1}{8}(a^2+2a-24)$ [Putting a for $8x$]

Now it can be easily seen that $a^2+2a-24=(a+6)(a-4)$

Hence the given expression

$=\frac{1}{8}(a+6)(a-4)$

$=\frac{1}{8}(8x+6)(8x-4)$

$=\frac{1}{8}\{2(4x+3)\times 4(2x-1)\}$

$=(4x+3)(2x-1)$

Example 11. Resolve into factors $12x^2+7x-10$

First Method : Find the product of *the co-efficient* of x^2 and *the term independent of* x, resolve the *product* into two factors whose *algebraic sum* is equal to the co-efficient of x

In the present case the *product*$=12\times(-10)=-120$

By trial, the factors of (-120), whose algebraic sum = the co-efficient of x, *i e*, $+7$, are $+15$ and -8

Thus the given expression

$=12x^2+15x-8x-10$

$=3x(4x+5)-2(4x+5)=(4x+5)(3x-2)$

Second Method : The given expression

$=12x^2+7x-10$

$=\frac{1}{12}(12\times 12x^2+7\times 12x-10\times 12)$

$=\frac{1}{12}(a^2+7a-120)$ [putting a for $12x$]

Now it can be easily seen that $a^2+7a-120=(a+15)(a-8)$

Hence the given expression

$=\frac{1}{12}(12x+15)(12x-8)$

$=\frac{1}{12}\{3(4x+5)\times 4(3x-2)\}=(4x+5)(3x-2)$

Example 12. Resolve into factors $13x^2-20ax+7a^2$

First Method : Find the product of *the co-efficient of* x^2 and *the term independent of* x In the present case, the product$=13\times 7a^2=91a^2$ Now, resolve $91a^2$ into two factors whose *algebraic sum* = co-efficient of x, *i e* $-20a$

By trial, the factors are $-7a$ and $-13a$

Thus, the given expression

$$=13x^2-13ax-7ax+7a^2$$
$$=13x(x-a)-7a(x-a)$$
$$=(x-a)(13x-7a)$$

Second Method : The given expression

$$=13x^2-20ax+7a^2$$
$$=\tfrac{1}{13}(13\times 13x^2-20a\times 13x+13\times 7a^2)$$
$$=\tfrac{1}{13}(y^2-20ay+91a^2) \qquad \text{[putting } y \text{ for } 13x\text{]}$$
$$=\tfrac{1}{13}(y^2-13ay-7ay+91a^2)$$
$$=\tfrac{1}{13}\{(y-13a)-7a(y-13a)\}$$
$$=\tfrac{1}{13}(y-13a)(y-7a)\,,$$

the exp $=\tfrac{1}{13}(13x-13a)(13x-7a)$

$$=\tfrac{1}{13}\times 13(x-a)(13x-7a)$$
$$=(x-a)(13x-7a)$$

EXERCISE 48.

Resolve into factors

1. x^2+3x+2	**2.** x^2+5x+6	**3.** a^2+4a+3
4. x^2-5x+4	**5.** $x^2+7x+10$	**6.** $x^2-7x+12$
7. $x^2+8x+15$	**8.** $x^2-2x-15$	**9.** $x^2-13x+36$
10. $x^2-5x-36$	**11.** $x^2-14x+24$	**12.** $x^2-22x+40$
13. $x^2+7x-30$	**14.** $x^2+2x-48$	**15.** $x^2+16x-36$
16. $x^2+9x-36$	**17.** $x^2+11x-42$	**18.** $x^2+14x-72$
19. $x^2-3x-40$	**20.** $x^2-11x-80$	**21.** $x^2-29x-96.$
22. $x^2-10x-56$	**23.** x^2-x-42	**24.** x^2-x-72
25. $x^2+22x+120$	**26.** $x^2+16x-80$	**27.** $x^2-21x-72$
28. $x^2+5x-84$	**29.** $x^2-20x+96$	**30.** $x^2+23x-78$
31. $x^2-6x-72$	**32.** $x^2-25x+84$	**33.** $x^2-26x+88$
34. $x^2+7x-120$	**35.** $x^2-2x-80.$	**36.** $x^2+8x-84$
37. a^2-a-56	**38.** $m^2-9m-90$	**39.** $a^2+17a-60.$
40. $a^2-15a+54$	**41.** $p^2-22p-48$	**42.** m^2+m-72
43. $m^2+27m-90$	**44.** $a^2-29a+120$	**45.** $x^2+7x-78$
46. $a^2-49a-102$	**47.** $a^2-19a+60$	**48.** $x^2+12x-64$

49. $a^2-26a-120$

50. $x^2+8x-105$

51. $x^2-xy-42y^2$

52. $a^2-12ab+32b^2$

53. $m^2+mn-30n^2$

54. $a^2+ab-12b^2$

55. $a^2-2ab-15b^2$

56. $x^2-7xy-8y^2$

57. $x^2+3xy-40y^2$

58. $p^2-14pq+48q^2$

59. $p^2+2pq-80q^2$

60. $x^2+20xy-96y^2$

61. a^4+4a^2-5

62. x^4+2x^2-15

63. x^4+3x^2-28

64. x^6+2x^3-3

65. a^6-10a^3+16

66. x^6+26x^3-27

67. a^6+7a^3-8

68. x^8-20x^4+64

69. a^8-11a^4-80

70. $x^{12}-7x^6-8$

71. $(a^2+2a)^2-(a^2+2a)-2$

72. $(x^2+3x)^2+3(x^2+3x)+2$

73. $(x^2-2x)^2-2(x^2-2x)-3$

74. $(a^2-3a)^2-3(a^2-3a)-4$

75. $(x^2-4x)^2-4(x^2-4x)-5$

76. $(x^2-x)^2-8(x^2-x)+12$

77. $(x^2-5x)^2+10(x^2-5x)+24$

78. $(a^2+7a)^2-8(a^2+7a)-180$

79. $(a^2+6a)^2-32(a^2+6a)-320$

80. $(x^2-8x)^2-29(x^2-8x)+180$

81. $2x^2+x-15$

82. $6a^2-a-15$

83. $8m^2-6m-9$

84. $6x^2+7xy-24y^2$

85. $10a^2-41ab+21b^2$

86. $12m^2-mn-20n^2$

87. $12x^2+28xy-5y^2$

88. $20a^2+ab-30b^2$

89. $18x^2-51xy+35y^2$

90. $12x^2+23xy-24y^2$

97. Quantities of the form x^2+px+q resolved into factors by expressing them as the difference of two squares.

The method will be best illustrated by the solution of a few typical cases

Example 1. Resolve into factors $x^2-7x+12$

$$x^2-7x+12=x^2-7x+(\tfrac{7}{2})^2-(\tfrac{7}{2})^2+12$$

[adding and subtracting $(\frac{7}{2})^2$]

$$=\{x^2-7x+(\tfrac{7}{2})^2\}-(\tfrac{49}{4}-12)$$
$$=(x-\tfrac{7}{2})^2-\tfrac{1}{4}$$
$$=\{(x-\tfrac{7}{2})+\tfrac{1}{2}\}\{(x-\tfrac{7}{2})-\tfrac{1}{2}\}$$
$$=(x-3)(x-4)$$

Note *It must be noticed that we have added to x^2-7x the square of half of 7 (i e, the square of the half the co-efficient of x) to get a perfect square Generally speaking x^2+2ax (or x^2-2ax) becomes a complete square when a^2 is added to it*

Example 2. Resolve into factors $x^2+2xy-8y^2-4z^2+12yz$

The given expression
$$=(x^2+2xy+y^2)-(9y^2+4z^2-12yz)$$
$$=(x+y)^2-(3y-2z)^2$$
$$=\{(x+y)+(3y-2z)\}\{(x+y)-(3y-2z)\}$$
$$=(x+4y-2z)(x-2y+2z)$$

Example 3. Resolve into factors $3x^2+11x-4$

$$3x^2+11x-4=3(x^2+\tfrac{11}{3}x-\tfrac{4}{3})$$
$$=3\{x^2+\tfrac{11}{3}x+(\tfrac{11}{6})^2-(\tfrac{11}{6})^2-\tfrac{4}{3}\}$$
$$=3\{(x+\tfrac{11}{6})^2-(\tfrac{121}{36}+\tfrac{4}{3})\}$$
$$=3\{(x+\tfrac{11}{6})^2-\tfrac{169}{36}\}$$
$$=3\{(x+\tfrac{11}{6})+\tfrac{13}{6}\}\{(x+\tfrac{11}{6})-\tfrac{13}{6}\}, \qquad [\tfrac{169}{36}=(\tfrac{13}{6})^2]$$
$$=3(x+4)(x-\tfrac{1}{3})=(x+4)(3x-1)$$

Example 4. Resolve into factors $8x^2-10x+3$

$$8x^2-10x+3=8\{x^2-\tfrac{10}{8}x+\tfrac{3}{8}\}$$
$$=8\{x^2-\tfrac{5}{4}x+(\tfrac{5}{8})^2-(\tfrac{25}{64}-\tfrac{3}{8})\}$$
$$=8\{(x-\tfrac{5}{8})^2-\tfrac{1}{64}\}$$
$$=8\{x-\tfrac{5}{8})+\tfrac{1}{8}\}\{(x-\tfrac{5}{8})-\tfrac{1}{8}\}$$
$$=8(x-\tfrac{1}{2})(x-\tfrac{3}{4})$$
$$=\{2(x-\tfrac{1}{2})\}\{4(x-\tfrac{3}{4})\}=(2x-1)(4x-3)$$

Example 5. Resolve into factors $2a^2+5ab-12b^2$

$$2a^2+5ab-12b^2=2(a^2+\tfrac{5}{2}ab-6b^2)$$
$$=2\left\{a^2+\frac{5}{2}ab+\left(\frac{5b}{4}\right)^2-\left(\frac{25b^2}{16}+6b^2\right)\right\}$$
$$=2\{(a+\tfrac{5}{4}b)^2-\tfrac{121}{16}b^2\}$$

$$=2\{(a+\tfrac{5}{4}b)+\tfrac{11}{4}b\}\{(a+\tfrac{5}{4}b)-\tfrac{11}{4}b\}$$
$$=2(a+4b)(a-\tfrac{3}{2}b)=(a+4b)(2a-3b)$$

Example 6. Resolve into factors $ax^2+(a^2+1)x+a$

$ax^2+(a^2+1)x+a$

$$=a\left\{x^2+\frac{a^2+1}{a}x+1\right\}$$
$$=a\left\{x^2+\frac{a^2+1}{a}\cdot x+\left(\frac{a^2+1}{2a}\right)^2-\left(\frac{a^4+2a^2+1}{4a^2}-1\right)\right\}$$
$$=a\left\{\left(x^2+\frac{a^2+1}{2a}\right)^2-\frac{a^4-2a^2+1}{4a^2}\right\}$$
$$=a\left\{\left(x+\frac{a^2+1}{2a}\right)+\frac{a^2-1}{2a}\right\}\left\{\left(x+\frac{a^2+1}{2a}\right)-\frac{a^2-1}{2a}\right\}$$
$$=a\left(x+a\right)\left(x+\frac{1}{a}\right)$$
$$=(x+a)(ax+1)$$

Similarly it may be shown that

$$ax^2-(a^2+1)x+a=(x-a)(ax-1),$$
$$ax^2+(a^2-1)x-a=(x+a)(ax-1),$$
$$ax^2-(a^2-1)x-a=(x-a)(ax+1)$$

Note *It is useful to remember these results as we are thus enabled to write down at once the factors of any expression which agrees in form with any of those considered above For instance, we can at once say that*

$$3x^2-10x+3=(x-3)(3x-1),$$
$$4x^2-15x-4=(x-4)(4x+1),$$
$$5x^2+24x-5=(x+5)(5x-1)\text{, and so on}$$

Example 7. Resolve into factors

$$4(x^2+2x+5)^2+17(x^2+2x+5)(x^2+6x)+4(x^2+6x)^2$$

Putting a for x^2+2x+5 and b for x^2+6x, the given expression becomes $4a^2+17ab+4b^2$ and it is easy to see that $4a^2+17ab+4b^2=(a+4b)(4a+b)$

Hence the given expression

$$=\{(x^2+2x+5)+4(x^2+6x)\}\{4(x^2+2x+5)+(x^2+6x)\}$$
$$=(5x^2+26x+5)(5x^2+14x+20)$$
$$=(x+5)(5x+1)(5x^2+14x+20)$$

EXERCISE 49.

Resolve the following expressions into factors applying the method of this article

1. x^2+4x+3 **2.** x^2+6x+5 **3.** $x^2+8x+15$

4. $x^2-10x+21$ **5.** $x^2-2x-48$ **6.** $x^2-4x-45$

7. $x^2-12x+32$ **8.** $x^2-6x-55$ **9.** $a^2+2ab-c^2+2bc$

10. x^2+2x-y^2+2y

11. x^2+6x-y^2+4y+5

12. $a^2+4ab-5b^2-c^2+6bc$

13. $x^2-6xy+5y^2-z^2+4yz$

14. $x^2-10xy+16y^2-4z^2+12yz$

15. $a^2-12ab-13b^2-9c^2+42bc$

16. $x^2+12xy-9z^2+36yz$

17. $x^2-14xy-15y^2-25z^2+80yz$ **18.** $2x^2-5x-3$

19. $3x^2-5x-2$ **20.** $3x^2+14x+8$ **21.** $4x^2+7x-2$

22. $6x^2+x-2$ **23.** $6x^2-5x-4$ **24.** $6x^2+7x-3$

25. $8x^2+2x-15$ **26.** $4x^2+4x-35.$ **27.** $6x^2-x-12.$

28. $3x^2-16x-12$ **29.** $2x^2-9x-35.$ **30.** $2x^2+5x-42$

31. $3x^2+13x-30$ **32.** $12x^2+x-6$

33. $2a^2+7ab-15b^2$ **34.** $6x^2-13xy+6y^2$

35. $6m^2-11mn-10n^2$ **36.** $3p^2+5pq-12q^2$

37. $8a^2-14ab-15b^2$ **38.** $10m^2+11mn-6n^2$

39. $12x^2+13xy-4y^2.$ **40.** $15a^2-11ab-12b^2$

41. $2a^2-5ab+2b^2$ **42.** $3a^2-8ab-3b^2.$

43. $3x^2+8xy-3y^2.$ **44.** $4a^2+15a-4$

45. $4a^2-17ab+4b^2$ **46.** $5x^2-24x-5$

47. $5x^2-26xy+5y^2$ **48.** $6x^2+37x+6$

49. $6a^2+35ab-6b^2$ **50.** $6a^2-35ab-6b^2$

51. $7a^2-50ab+7b^2$ **52.** $7a^2+48ab-7b^2$

53. $7a^2-48ab-7b^2$ **54.** $8x^2+63xy-8y^2$

55. $9x^2-82xy+9y^2$ **56.** $10x^2+99xy-10y^2$

57. $2(a+b)^2+3(a+b)-2$

58. $2(x^2+y^2)^2-3xy(x^2+y^2)-2x^2y^2$

59. $2(a^2+b^2)^2+5ab(a^2+b^2)+2a^2b^2$

60. $4(x^2-4xy+y^2)^2+15xy(x^2-4xy+y^2)-4x^2y^2$

61. $2x^4-5x^2-12$

62. $8a^4-14a^2b^2-9b^4$

63. $9a^4+2a^2b^2-32b^4$

64. $8x^6-65x^3+8$

65. $4a^8-17a^4b^4+4b^8$

CHAPTER XIII

EASY IDENTITIES

98. We have explained the significance of Identity in Art 62 In fact, an **identity** is a statement that two expressions are equal for *all* values of the letters involved Each of the two expressions constituting an identity is called a *side* or a *member* of the identity

Thus, $5x=2x+3x$ is an identity, since the expressions $5x$ and $2x+3x$ are equal for all values of x The sides of this identity are $5x$ and $2x+3x$, $5x$ being the *left-hand* side and $2x+3x$, the *right-hand* side

Similarly $(a+b)^2=a^2+2ab+b^2$ is an identity, since the equality of both sides holds for all values of a and b As a matter of fact, every formula established in Chapter IV is an identity

99. An identity is proved when its two sides are shown to be equal

To establish the equality of the two sides of an identity, reduce each side to its simplest form Identity is proved if these forms are found to be equal A better method, however, is to reduce one of the sides of the identity to the form of the other by simplification and transformation with the aid of the formulæ enumerated in Chapter XI

Sometimes the sides of an identity may be conveniently expressed in simpler forms by substituting letters for groups of terms in the identity Such substitutions must be effected wherever necessary

The following examples will illustrate the process

Example 1. Prove that $(a+3b)^2+(a-3b)^2=2a^2+18b^2$

The left side $=(a^2+6ab+9b^2)+(a^2-6ab+9b^2)$ [Arts 54 and 55]

$$=2a^2+18b^2$$

Example 2. Prove that

$$a^2+b^2+c^2-ab-bc-ca=\tfrac{1}{2}[(b-c)^2+(c-a)^2+(a-b)^2]$$

The left-hand side

$$=\tfrac{1}{2}[2a^2+2b^2+2c^2-2ab-2bc-2ca]$$
$$=\tfrac{1}{2}[(a^2+b^2)+(b^2+c^2)+(c^2+a^2)-2ab-2bc-2ca]$$
$$=\tfrac{1}{2}[(b^2-2bc+c^2)+(c^2-2ca+a^2)+(a^2-2ab+b^2)]$$
$$=\tfrac{1}{2}[(b-c)^2+(c-a)^2+(a-b)^2] \qquad \text{[Art 55]}$$

Example 3. Prove that

$$(x+5y-3z)^3+(x-5y+3z)^3+6x(x+5y-3z)(x-5y+3z)=8x^3$$

Substituting a for $x+5y-3z$ and b for $x-5y+3z$, we have

the left-hand side $=a^3+b^3+6x\,ab$

$$=a^3+b^3+3ab(a+b)$$

[since, $a+b=(x+5y-3z)$
$+(x-5y+3z)=2x$]

$$=(a+b)^3 \qquad \text{[Art 57]}$$
$$=(2x)^3$$
$$=8x^3$$

Example 4. Prove that

$$(b+c)(b-c)+(c+a)(c-a)+(a+b)(a-b)=0$$

The left-hand side $=(b^2-c^2)+(c^2-a^2)+(a^2-b^2)$ [Art 56]

$$=b^2-c^2+c^2-a^2+a^2-b^2$$
$$=0$$

Example 5. If $s=a+b+c$, prove that

$(as+bc)(bs+ca)(cs+ab)=(a+b)^2(b+c)^2(c+a)^2$ [C U 1902]

$$as+bc=a(a+b+c)+bc$$
$$=a^2+a(b+c)+bc=a^2+ab+ac+bc$$
$$=a(a+b)+c(a+b)=(a+b)(a+c)$$

[Art 61]

Similarly, $bs+ca=b(a+b+c)+ca=b^2+b(a+c)+ac$
$$=b^2+ab+bc+ac=(b+c)(b+a).$$

and $cs+ab=c(a+b+c)+ab=c^2+c(a+b)+ab$
$$=c^2+ca+cb+ab=(c+a)(c+b)$$

The left-hand side
$$=(a+b)(a+c)(b+c)(b+a)(c+a)(c+b)$$
$$=(a+b)^2(b+c)^2(c+a)^2$$

Example 6. Prove that $4a^2b^2-(a^2+b^2-c^2)^2$
$$=s(s-2a)(s-2b)(s-2c) \text{ where } s=a+b+c$$

The left-hand side $=(2ab)^2-(a^2+b^2-c^2)^2$
$$=\{2ab+(a^2+b^2-c^2)\}\{2ab-(a^2+b^2-c^2)\}$$
$$=\{(a^2+2ab+b^2)-c^2\}\{c^2-(a^2+b^2-2ab)\}$$
$$=\{(a+b)^2-c^2\}\{c^2-(a-b)^2\}$$
$$=(\overline{a+b}+c)(\overline{a+b}-c)(c+\overline{a-b})(c-\overline{a-b})$$
$$=(a+b+c)(a+b-c)(c+a-b)(c-a+b)$$
$$=(a+b+c)(\overline{a+b+c}-2c)(\overline{c+a+b}-2b)$$
$$\times(\overline{b+c+a}-2a)$$
$$=s(s-2c)(s-2b)(s-2a)$$
$$=s(s-2a)(s-2b)(s-2c)$$

Example 7. If $2s=a+b+c$ prove that
$$(s-a)^3+(s-b)^3+3(s-a)(s-b)c=c^3$$

We have, $c=2s-(a+b)=(s-a)+(s-b)$

Hence $(s-a)^3+(s-b)^3+3(s-a)(s-b)c$
$$=(s-a)^3+(s-b)^3+3(s-a)(s-b)\{(s-a)+(s-b)\}$$
$$=\{(s-a)+(s-b)\}^3=c^3$$

Example 8. Prove that $(x-y)^2+(y-z)^2+(z-x)^2$
$$=2(x-y)(x-z)+2(y-z)(y-x)+2(z-x)(z-y)$$

Putting $\left.\begin{array}{l} a \text{ for } x-y \\ b \text{ for } y-z \\ c \text{ for } z-x \end{array}\right\}$ we have $a+b+c=0$

Hence, $\{(x-y)^2+(y-z)^2+(z-x)^2\}$
$$-\{2(x-y)(x-z)+2(y-z)(y-x)+2(z-x)(z-y)\}$$

$$=(a^2+b^2+c^2)-\{2a(-c)+2b(-a)+2c(-b)\}$$
$$=a^2+b^2+c^2+2ac+2ab+2bc$$
$$=(a+b+c)^2=0,$$

$$(x-y)^2+(y-z)^2+(z-x)^2$$
$$=2(x-y)(x-z)+2(y-z)(y-x)+2(z-x)(z-y)$$

Example 9. If $2s=a+b+c$, show that

$$2(s-a)(s-b)+2(s-b)(s-c)+2(s-c)(s-a)=2s^2-a^2-b^2-c^2$$

Since, $2x+2y+2z=(x+y)+(y+z)+(z+x)$,

we must have, $2(s-a)(s-b)+2(s-b)(s-c)+2(s-c)(s-a)$
$$=\{(s-a)(s-b)+(s-b)(s-c)\}+\{(s-b)(s-c)+(s-c)(s-a)\}$$
$$+\{(s-c)(s-a)+(s-a)(s-b)\}$$

Now, $(s-a)(s-b)+(s-b)(s-c)=(s-b)\{(s-a)+(s-c)\}$
$$=(s-b)\{2s-a-c\}=(s-b)b$$

Similarly, $(s-b)(s-c)+(s-c)(s-a)=(s-c)c$

and $(s-c)(s-a)+(s-a)(s-b)=(s-a)a$

Hence, the given expression $=(s-b)b+(s-c)c+(s-a)a$
$$=s(b+c+a)-b^2-c^2-a^2$$
$$=2s^2-a^2-b^2-c^2$$

Example 10. If $a+b+c=0$, prove that $a^3+b^3+c^3=3abc$

Since, $a+b+c=0$, $c=-(a+b)$

The left-hand side $=a^3+b^3+\{-(a+b)\}^3$
$$=a^3+b^3-\{a^3+b^3+3ab(a+b)\}$$
[Art 57]

$$=-3ab(a+b)$$
$$=3ab\{-(a+b)\}=3abc$$

Note *Evidently the identity $a^3+b^3+c^3=3abc$ is true only if $a+b+c=0$ Such identities which are true only for some particular values of the symbols involved is called* ***Conditional Identities.***

Example 11. If $a+b+c=0$, prove that

$a^2+ab+b^2=b^2+bc+c^2=c^2+ca+a^2$ [Allahabad, 1923]

Since $a+b+c=0$, we have by transposition

$$a=-(b+c)$$
$$b=-(c+a)$$
$$c=-(a+b)$$

$\therefore \quad a^2+ab+b^2=\{-(b+c)\}^2+\{-(b+c)\}b+b^2,$ [since $a=-(b+c)$]

$$=(b+c)^2-(b+c)b+b^2$$
$$=b^2+2bc+c^2-b^2-bc+b^2$$
$$=b^2+bc+c^2$$

Also $a^2+ab+b^2=a^2+a\{-(c+a)\}+\{-(c+a)\}^2,$ [since $b=-(c+a)$]

$$=a^2-a(c+a)+(c+a)^2$$
$$=a^2-ca-a^2+c^2+2ca+a^2$$
$$=c^2+ca+a^2$$

Hence $a^2+ab+b^2=b^2+bc+c^2=c^2+ca+a^2$

Alternative Method : $a^2+ab+b^2=a(a+b)+b^2$

$$=\{-(b+c)\}(-c)+b^2=(b+c)c+b^2$$
$$=bc+c^2+b^2=b^2+bc+c^2$$

Also $b^2+bc+c^2=b(b+c)+c^2$

$$=\{-(c+a)\}(-a)+c^2$$
$$=(c+a)a+c^2=ca+a^2+c^2$$
$$=c^2+ca+a^2$$

Hence $a^2+ab+b^2=b^2+bc+c^2=c^2+ca+a^2$

Example 13. If $x=b-c+a$, $y=c-a+b$, $z=a-b+c$ prove that $(b-a)x+(c-b)y+(a-c)z=0$

We have

$(b-a)x=(b-a)(b-c+a)=(b-a)\{(b+a)-c\}$

$=(b-a)(b+a)-(b-a)c=b^2-a^2-bc+ac,$ [Art 56]

$(c-b)y=(c-b)(c-a+b)=(c-b)\{(c+b)-a\}$

$=(c-b)(c+b)-(c-b)a=c^2-b^2-ca+ab,$

$(a-c)z=(a-c)(a-b+c)=(a-c)\{a+c-b\}$

$=(a-c)(a+c)-(a-c)b=a^2-c^2-ab+bc$

$(b-a)x+(c-b)y+(a-c)z$

$=b^2-a^2+c^2-b^2+a^2-c^2-bc+ac-ca+ab-ab+bc=0.$

Example 13. If $x=b+c$, $y=c+a$, $z=a+b$, prove that

$$x^2+y^2+z^2-yz-zx-xy=a^2+b^2+c^2-bc-ca-ab$$

The left side $=\frac{1}{2}[2x^2+2y^2+2z^2-2yz-2zx-2xy]$

$=\frac{1}{2}[(x^2-2xy+y^2)+(y^2-2yz+z^2)+(z^2-2zx+x^2)]$

[re-arranging terms]

$=\frac{1}{2}[(x-y)^2+(y-z)^2+(z-x)^2]$ [Art 55]

$=\frac{1}{2}[\{(b+c)-(c+a)\}^2+\{(c+a)-(a+b)\}^2+\{(a+b)-(b+c)\}^2]$

[substituting for x, y, z]

$=\frac{1}{2}[(b-a)^2+(c-b)^2+(a-c)^2]$

$=\frac{1}{2}[(b^2-2ba+a^2)+(c^2-2cb+b^2)+(a^2-2ac+c^2)]$

[Art 55]

$=\frac{1}{2}[(2a^2+2b^2+2c^2-2bc-2ca-2ab)]$ [collecting terms]

$=a^2+b^2+c^2-bc-ca-ab$

Example 14. If $2s=a+b+c$, prove that

$(s-a)^2+(s-b)^2+(s-c)^2+s^2=a^2+b^2+c^2$ [Allahabad, 1926]

The left-hand side

$=(s^2-2as+a^2)+(s^2-2bs+b^2)+(s^2-2cs+c^2)+s^2$

$=4s^2-2s(a+b+c)+a^2+b^2+c^2$

$=4s^2-2s\times 2s+a^2+b^2+c^2$

$=4s^2-4s^2+a^2+b^2+c^2=a^2+b^2+c^2$

EXERCISE 50.

Show that

1. $(a^2+ax-x^2)(a^2-ax+x^2)=a^4-a^2x^2+2ax^3-x^4$

2. $(a^2-ax+x^2)(ax-a^2+x^2)=x^4-a^2x^2+2a^3x-a^4$

3. $(a+b+c)(a-b-c)+(b+c-a)(a-b+c)=2b(a-b-c)$

4. $2(x^3-x)+3x(x+1)=x(x+1)(2x+1)$

5. $x^4+x+x(x+1)(2x+1)-2x(x+1)=x^2(x+1)^2$

6. $(a^2+b^2)(c^2+d^2)=(ac-bd)^2+(ad+bc)^2$

7. $(a+b)^2-(c+d)^2+(a+c)^2-(b+d)^2$

$=2(a+b+c+d)(a-d)$

8. $(a+b+c-d)(d-a-b+c)=c^2-(a+b-d)^2$

9. The product of $(b+c)^2-a^2$ and $a^2-b^2-c^2+2bc$ is $2a^2b^2+2a^2c^2+2b^2c^2-a^4-b^4-c^4$

10. $(a+b+c)^2-(a+b-c)^2+(a+c-b)^2-(b+c-a)^2=8ac$

Prove that.

11. $(a^2+b^2+c^2)^2-(b^2+c^2-a^2)^2-(a^2-b^2+c^2)^2$
$+(a^2+b^2-c^2)^2=8a^2b^2.$

12. $(b-c+d+a)(d+a-b+c)+(c-d+a+b)(b+c+d-a)$
$=4(ad+bc).$

13. $(b+c+a-d)(b+c-a+d)=2(ad+bc)-(a^2-b^2-c^2+d^2).$

14. $4(ad+bc)^2-(a^2-b^2-c^2+d^2)^2$
$=(a+d+b-c)(a+d-b+c)(b+c+a-d)(b+c-a+d).$

15. $(x-y+z)^2+(y-z+x)^2+(z-x+y)^2$
$+2(x-y+z)(y-z+x)+2(y-z+x)(z-x+y)$
$+2(z-x+y)(x-y+z)=(x+y+z)^2.$

16. $(a^2+b^2+c^2)(x^2+y^2+z^2)-(ax+by+cz)^2$
$=(ay-bx)^2+(cx-az)^2+(bz-cy)^2.$

17. $(a+c)^3-(b+c)^3-3(a+c)(b+c)(a-b)=(a-b)^3$

18. $(x-ay+bz)^3+(x+ay-bz)^3+6x(x-ay+bz)(x+ay-bz)$
$=8x^3.$

19. $4(a+b+c)^2=(a+b)^2+(b+c)^2+(c+a)^2$
$+2(a+b)(b+c)+2(b+c)(c+a)+2(c+a)(a+b).$

20. $8(a+b+c)^3=(a+b)^3+(b+2c+a)^3$
$+6(a+b)(b+2c+a)(a+b+c).$

21. $27(a+b+c)^3=(a+3b+2c)^3+(2a+c)^3$
$+9(a+3b+2c)(2a+c)(a+b+c).$

22. If $s=a+b+c$, show that
$(s-3a)^2+(s-3b)^2+(s-3c)^2=3\{(a-b)^2+(b-c)^2+(c-a)^2\}.$

23. If $ab+bc+ca=0$, prove that

(i) $a^2+b^2+c^2=(a+b+c)^2$.

(ii) $a^2b^2+b^2c^2+c^2a^2=-2abc(a+b+c)$

24. If $2s=x+y+z$, prove that
$4y^2z^2-(y^2+z^2-x^2)^2=16s(s-x)(s-y)(s-z)$

25. Prove that
$(x+2y+19z)^3+(x-2y-19z)^3+6x(x+2y+19z)(x-2y-19z)$
$=(5x+6y-z)^3+(z-6y-3x)^3+6x(5x+6y-z)(z-6y-3x).$

26. Prove that
$(a+2b+3c)^2+(a-b-3c)^2+2(a+2b+3c)(a-b-3c)$
$=(3a+y+z)^2+(a+y+z-b)^2-2(3a+y+z)(a+y+z-b).$

27. Show that

$$(x-y)^3+(y-z)^3+(z-x)^3=3(x-y)(y-z)(z-x)$$

28. Prove that $(x-y)^2-(y-z)(z-x)$
$$=(y-z)^2-(z-x)(x-y)$$
$$=(z-x)^2-(x-y)(y-z)$$
$$=-\{(x-y)(y-z)+(y-z)(z-x)+(z-x)(x-y)\}$$

29. Prove that $(a-b)^2-(b-c)^2-(c-a)^2=2(b-c)(c-a)$
$$(b-c)^2-(c-a)^2-(a-b)^2=2(c-a)(a-b)$$
$$(c-a)^2-(a-b)^2-(b-c)^2=2(a-b)(b-c)$$

30. Prove that $(a-b)^2+(a-b)(b-c)+(b-c)^2$
$$=(b-c)^2+(b-c)(c-a)+(c-a)^2$$
$$=(c-a)^2+(c-a)(a-b)+(a-b)^2$$

Miscellaneous Exercises. III

I

1. Arrange the following expression (i) according to descending powers of y and (ii) according to ascending powers of z

$$x^3z+xy^3-x^3y-xy^2z-xz^3+xyz^2-2yz^3-2y^3z$$

2. Find the value of

$$\frac{4y}{5}(y-x)-35\left[\frac{3x-4y}{5}-\frac{1}{10}\left\{3x-\frac{5}{7}\left(7x-4y\right)\right\}\right],$$

when $x=-\frac{1}{2}$ and $y=2$

3. If $x-\dfrac{1}{x}=p$ prove that $x^3-\dfrac{1}{x^3}=p^3+3p$

4. Write down the quotient of x^5-y^5 by $x-y$

5. Simplify $(a+b+c)^2-(a-b+c)^2+(a+b-c)^2-(b+c-a)^2$, and find its numerical value when $a=b=c=-4$

6. Find the sum of $x^2-(x-y+z)(x+y-z)$, $y^2-(y-x+z)(y+x-z)$ and $z^2-(z-x+y)(z+x-y)$

7. Reduce $(a-b+c+d)(a+b+c-d)$ to the form A^2-B^2

8. Resolve into factors $4x^2+12xy+9y^2-8x-12y$

II

1. Find an expression which exceeds $ax^3+bx^2y+3cxy^2+dy^3$ by as much as it falls short of four times

$$2ax^3+\tfrac{1}{4}(3a-b)x^2y+\tfrac{3}{4}(3a-c)xy^2+5dy^3$$

2. Resolve the sum of the following expressions into simple factors

$(b-1)m^4+am^3+(c-b)m^2-bm-2$, $am^3-(c-a)m^2+(a+b)m+1$ and $(a-b+1)m^4-(2a-b)m^3+(a+b)m^2-(a-2b)m+1$

3. Multiply $x^{\frac{2}{3}}+2x^{\frac{1}{2}}+3x^{\frac{1}{3}}+2x^{\frac{1}{6}}+1$ by $x^{\frac{1}{3}}-2x^{\frac{1}{6}}+1$

4. Prove that

$$\{(ac+bd)x+(ad-bc)y\}^2+\{(ac+bd)y-(ad-bc)x\}^2 = (a^2+b^2)(c^2+d^2)(x^2+y^2)$$

5. Find the continued product of $x-a$, $x-b$ and $x-c$. Hence show that $(x-3)^3=x^3-9x^2+27x-27$

6. Divide $x^5-px^4+qx^3-qx^2+px-1$ by $x-1$

7. Find the quotient when the product of $a^6+a^5b-a^3b^3+ab^5+b^6$ and a^2-ab+b^2 is divided by $a^4-a^2b^2+b^4$ and show that its defect from $(a^2+b^2)^2$ is a^2b^2

8. Resolve into factors

(i) $ab-ac-b^2+bc$ (ii) $b^2-12ac-4a^2-9c^2$

III

1. Find the sum of

$(\sqrt{b}-\sqrt{c}+\sqrt{a})x^3+(\sqrt{bc}-\sqrt{ca}+\sqrt{ab})x^2+(\sqrt{abc}-2m+n)x+3u$, $(\sqrt{c}-\sqrt{a}+\sqrt{b})x^3+(\sqrt{ca}-\sqrt{ab}+\sqrt{bc})x^2+(\sqrt{abc}-2n+m)x+2(v-u)$ and $(p-2\sqrt{b})x^3+(q-2\sqrt{bc})x^2+(m+n-r-2\sqrt{abc})x+(s-u-2v)$

2. Subtract the sum of $3a^3-5a^2b+2b^3$, $8a^2b-3b^3+2ab^2$, $5ab^2-4a^3-3a^2b$ and $2a^3-6ab^2+4b^3$ from $a(a^2+b^2)$

3. If $a+b=8$ and $ab=5$, find the value of a^3+b^3

4. Find the value of $49c^2+9(a+b)^2-42(a+b)c$,

when $a=89$, $b=-69$ $c=8$

5. Divide $x^3(y-z)+y^3(z-x)+z^3(x-y)$ by y^2-xz-z^2+xy

6. Resolve into factors $4a-3+16a^2+64a^3$ after reducing it to the form of $(A-B)+(A^2-B^2)+(A^3-B^3)$.

7. Show that $(1+x+x^2)^2-(1-x+x^2)^2=4x(1+x^2)$

8. If $a_1+a_2+a_3+\quad\quad+a_n=\frac{n}{2}s$, show that

$$(s-a_1)^2+(s-a_2)^2+(s-a_3)^2+\quad\quad+(s-a_n)^2$$
$$=a_1{}^2+a_2{}^2+a_3{}^2+\quad+a_n{}^2$$

IV

1. Simplify the expression

$$(l^2r-3lmn+2m^3)p^3+3(lmr+m^2n-2ln^2)\,p^2q$$
$$+3(2m^2r-lnr-mn^2)pq^2+(3mnr-lr^2-2n^3)q^3$$

where $p=-m$ and $q=l$

2. What must be subtracted from $\frac{1}{7}a^3x^4+5.7a^2bx^3-3.257ab^2x^2+\frac{5}{3}b^3x+9$ so as to make the difference equal to the sum of $4.7a^2bx^3-.007ab^2x^2+2\frac{2}{3}b^3x-5\frac{2}{3}a^3x^4+6$, $5\frac{1}{3}b^3x-3\frac{1}{3}a^2bx^3+a^3x^4-.05ab^2x^2+11$ and $2a^3x^4-1\frac{2}{7}a^2bx^3-6.2ab^2x^2-10\frac{1}{4}b^3x-20$?

3. Multiply

$$a^{\frac{5}{2}}-2a^2b^{\frac{1}{3}}+4a^{\frac{2}{3}}b^{\frac{2}{3}}-8ab+16a^{\frac{1}{2}}b^{\frac{4}{3}}-32b^{\frac{5}{3}} \text{ by } a^{\frac{1}{2}}+2b^{\frac{1}{3}}$$

4. Arrange the following expressions according to descending powers of a

(i) $a^3+b^3+c^3-3abc$,

(ii) $a^2(b-c)+b^2(c-a)+c^2(a-b)$,

(iii) $a^4(b-c)+b^4(c-a)+c^4(a-b)$

5. Find the product of $x+a$, $x+b$ and $x+c$
Hence, deduce the co-efficients of x^2 and x in

$$(x-7)(x+8)(x-12)$$

6. Prove that $(ab+cd+ac+bd)(ab+cd-ac-bd)$
$$=a^2b^2+c^2d^2-a^2c^2-b^2d^2$$

7. If $a=q+r+s$, $b=r+s-p$, $c=p+q+r$,
prove that $a^2+b^2+c^2-2ab-2ac+2bc=r^2$

8. Divide $a^3+8b^3+27c^3-18abc$
by $a^2+4b^2+9c^2-6bc-3ca-2ab$

V

1. Find the value of

$$49a^2+126ab+81b^2, \text{ when } a=46\quad b=-37$$

2. Find the expression which falls short of $bx^4y - dx^2y^3 - fy^5$ by as much as it exceeds $ax^5 - cx^3y^2 + exy^4$

3. If $2s = a + b + c$, show that

$$(s-a)^2 + (s-b)^2 + (s-c)^2 + s^2 = a^2 + b^2 + c^2$$

4. Simplify $(5a-7c)^3 + (8c-3a)^3 + 3(2a+c)(5a-7c)(8c-3a)$.

5. Reduce the following to its simplest form

$$(2x^3 - x^2 + 3x - 4)(2x^3 + x^2 + 3x + 4)$$
$$+ (2x^3 + x^2 - 3x + 4)(2x^3 + x^2 + 3x - 4).$$

6. Show that

$$\frac{x^8 + x^4 + 1}{x + \sqrt{x} + 1} = (x - \sqrt{x} + 1)(x^2 - x + 1)(x^4 - x^2 + 1)$$

7. Divide $a - b$ by $a^{\frac{1}{4}} - b^{\frac{1}{4}}$

8. Resolve into factors

(i) $6a^4x^2 + a^3x - 6a^3x^3 - a^2x^2$

(ii) $xy(1 + z^2) + z(x^2 + y^2)$

VI

1. Find the value of

$$8765943 \times 8765943 - 8765938 \times 8765938$$

2. Find the value of

$27a^3 + 108a^2b + 144ab^2 + 64b^3$, when $a = 29$, $b = -23$

3. Divide $a^3 + b^3 + c^3 - 3abc$ by $a + b + c$, and hence show that $a^3 + b^3 + c^3 - 3abc = \frac{1}{2}(a+b+c)\{(a-b)^2 + (b-c)^2 + (c-a)^2\}$

4. Find the quotient when $(ax+b)^2 + (cx+d)^2 + (bx-a)^2 + (dx-c)^2$ is divided by $a^2 + b^2 + c^2 + d^2$

5. Express $(x-1)(x-3)(x-4)(x-6) + 34$ as the sum of two squares, hence show that it is always a positive quantity and that its value is equal to 25 when $x^2 - 7x + 9 = 0$

6. Resolve $(a^2 - b^2 - c^2 + d^2)^2 - 4(ad - bc)^2$ into four factors.

7. Resolve into factors

(i) $a^2 - 2ab + b^2 + 2a - 2b$, (ii) $6a^2 - ab - b^2 + 6a - 3b$,

(iii) $15x^2 - 4xy - 4y^2 + 10x + 4y$

8. Divide $(2x-y)^2a^4 - (x+y)^2a^2x^2 + 2(x+y)ax^4 - x^6$ by $(2x-y)a^2 - (x+y)ax + x^3$.

VII

1. If $x+y+z=8$ and $x^2+y^2+z^2=50$, find the value of $xy+yz+zx$

2. Prove that $(2a-3b)^2+(3b-5c)^2+(5c-2a)^2$
$=2(2a-3b)(2a-5c)+2(3b-5c)(3b-2a)+2(5c-2a)(5c-3b)$

3. Find the product of

$$x+y+z-x^{\frac{1}{2}}y^{\frac{1}{2}}-y^{\frac{1}{2}}z^{\frac{1}{2}}-z^{\frac{1}{2}}x^{\frac{1}{2}} \text{ and } x^{\frac{1}{2}}+y^{\frac{1}{2}}+z^{\frac{1}{2}}$$

4. Divide $a^2(x^2-a^2)-ab(x+a)^2+b(x^3+a^3)$
by $a^2(x-a)+bx(x-2a)$

5. Show that

$(16x^5-20x^3+5x)^2+(1-x^2)\{16(1-x^2)^2-20(1-x^2)+5\}^2=1$

6. Find the continued product of

$$x+y+z,\ x-y+z,\ x+y-z \text{ and } z-x+y$$

7. Resolve into factors

(i) $6x^2+x-15$, (ii) $35(x-y)^2-41(x-y)+12$,
(iii) $11x^2-54xy^2+63y^4$

8. If $x+y+z=0$, show that
$(x+y)(y+z)(z+x)=-xyz$ and $x^3+y^3+z^3=3xyz$

VIII

1. Multiply together the expressions $1+ax+\frac{a(a-1)}{2}x^2$ and $1+bx+\frac{b(b-1)}{2}x^2$ as far as the term involving x^2

2. If $x+y+z=15$ and $xy+yz+zx=85$, find the value of $x^2+y^2+z^2$

3. If $a^2+b^2=1=c^2+d^2$, show that

$$(ad-bc)(ad+bc)=(a-c)(a+c)$$

4. Divide $(ax+by)^3+(ax-by)^3+(bx-ay)^3+(bx+ay)^3$
by $(a+b)^2x^2-3ab(x^2-y^2)$.

5. Evaluate $x^2+\frac{1}{x^2}$, $x^3+\frac{1}{x^3}$ and $x^4+\frac{1}{x^4}$, when $x+\frac{1}{x}=a$

6. If $bx=ay$, prove that $(x^2+y^2)(a^2+b^2)=(ax+by)^2$
[B U 1910]

7. Show that $(x^2+y^2)(x^2+z^2)+2x(x^2+yz)(y+z)+4x^2yz$
$$=(x^2+xy+xz+yz)^2$$

8. Resolve into factors $x^4-11x^2y^2+y^4$ [B U 1897]

IX

1. Multiply a^2+ax+x^2 by a^2-ax+x^2

2. Show that $(a^2+2ab+b^2-c^2)(a^2-2ab+b^2+c^2)$
$$=(a^2-b^2)^2+(4ab-c^2)c^2$$

3. If $a^2+b^2=1=c^2+d^2$ show that
$$(ac-bd)^2+(ad+bc)^2=1$$

4. Write down the expansion of $\left(x+\dfrac{2}{x}\right)^3$

5. Show that $(a^2+ab\sqrt{2}+b^2)(a^2-ab\sqrt{2}+b^2)=a^4+b^4$

6. Divide $a^3(b^2-c^2)+b^3(c^2-a^2)+c^3(a^2-b^2)$ by $ab+bc+ca$

7. Show that $(x-a)^2(b-c)+(x-b)^2(c-a)+(x-c)^2(a-b)$
$$=a^2(b-c)+b^2(c-a)+c^2(a-b)$$

8. Solve the equation $(7+x)(8-x)-\dfrac{7x}{3}=17x+1-x^2$

X

1. If $x+\dfrac{1}{x}=2(a+m)$, $x-\dfrac{1}{x}=2b$ $y+\dfrac{1}{y}=2(c+n)$ and $y-\dfrac{1}{y}=2d$, find the value of $xy+\dfrac{1}{xy}$

2. Simplify $\left(\dfrac{a}{b}+\dfrac{b}{a}\right)^4-2\left(\dfrac{a^2}{b^2}-\dfrac{b^2}{a^2}\right)^2+\left(\dfrac{a}{b}-\dfrac{b}{a}\right)^4$

3. Show that
$(1+a)^2(1+c^2)-(1+c)^2(1+a^2)=2(a-c)(1-ac)$

4. Show that $(b^2-c^2)(b+c-2a)^2+(c^2-a^2)(c+a-2b)^2$
$$+(a^2-b^2)(a+b-2c)^2=0, \text{ if } a+b+c=0$$

5. Multiply $a+b^{\frac{2}{3}}+c^{\frac{1}{2}}-b^{\frac{1}{3}}c^{\frac{1}{4}}-c^{\frac{1}{4}}a^{\frac{1}{2}}-a^{\frac{1}{2}}b^{\frac{1}{3}}$ by $a^{\frac{1}{2}}+b^{\frac{1}{3}}+c^{\frac{1}{4}}$

6. Resolve $15x^2-41x+14$ into simple factors

7. Find the value of x for which
$$\frac{x-1}{4}-\frac{2(x+1)}{9}+\frac{5(x-5)}{12}-4=\frac{x+1}{18}.$$

8. A and B have the same income A lays by a fifth of his income but B, by spending annually £30 more than A, at the end of 4 years finds himself £220 in debt What was their income?

CHAPTER XIV

HIGHEST COMMON FACTORS

(*By factorisation*)

100. Definitions. A *common factor* of two or more algebraical expressions is an expression which divides each of them without a remainder

N B By ***expressions*** *we shall mean* ***rational*** *and* ***integral expressions*** *only*

[See Note, Art 91]

An *elementary* common factor is one which cannot itself be resolved into factors

The product of *all* the *elementary* common factors of two or more expressions is called their **Highest Common Factor ;** or, in other words, the Highest Common Factor of two or more expressions is that common factor which is formed by the product of the *greatest* number of elementary common factors.

Thus, since $6a^2b(x^2-1)=2\times3\times a\times a\times b\times(x+1)\times(x-1)$, and $15ab^2(x^2-3x+2)=3\times5\times a\times b\times b\times(x-1)\times(x-2)$, the elementary common factors of the two expressions on the left are 3 a, b, and $x-1$, hence, their H C F $=3ab(x-1)$

Note 1 *Other common factors of the given expressions are* $3a$, $b(x-1)$, ab, $3(x-1)$, $3ab$, *&c, but none of them is elementary*

Note 2 *When the expressions considered have no* ***numerical*** *common factor, it is easy to comprehend that the Highest Common Factor is an expression of the higher degree than any other common factor Hence, when two or more expressions have no numerical factor common, their Highest Common Factor may be defined to be the expression of the highest degree by which each of them is divisible without a remainder*

Note 3 *If any expression A divides any other expression B without a remainder, then A is evidently the H C.F of A and B*

Note 4 *If H be the H C F of any number of quantities A, B, C, &c, then the quotients of A, B, C, &c, by H have no common factor*

Note 5 *If an elementary factor occurs more than once in each of two or more given expressions then the* **highest** *power of this factor* **common** *to the given expressions, and no higher power,* **must** *occur as a factor in the H C F of these expressions*

Note 6 *If $A=p\times q$, and $B=p'\times q'$, such that q and q' have no common factor, then the H C F of A and B, if any, will be the same as the H C F of p and p'*

Note 7 *If $A=m\times n$, and $B=m'\times n'$, where m and m' respectively include* **all** *the monomial factors of A and B then the H C F of A and $B=$(the H C F of m and m')$\times$(the H C F of n and n')*

Note 8 *The H C F of A and B is the same as the H C F of A and mB, if m is not a factor of A*

101. Highest Common Factors of simple expressions. Such expressions can be at once resolved into their elementary factors, and so there is no difficulty in finding the H C F of any number of them

Example 1. Find the H C F of $a^2b^4c^5$, $a^4b^3c^7$ and $a^3b^5c^4$

The elementary common factors are a, b and c, and the *highest* powers of them *common* to the given expressions are respectively, a^2, b^3 and c^4

Hence, the H C F required $=a^2b^3c^4$

Example 2. Find the H C F of $24ab^2x^3y^4$, $36a^2x^4z^5$ and $240b^3x^6y^2z$

We have
$$24ab^2x^3y^4 = 3\times 2^3\times ab^2x^3y^4,$$
$$36a^2x^4z^5 = 2^2\times 3^2\times a^2x^4z^5,$$
$$240b^3x^6y^2z = 3\times 5\times 2^4\times b^3x^6y^2z$$

Evidently then the elementary common factors are 3, 2 and x, and the highest powers of them common to the given expressions are respectively 3, 2^2 and x^3

Hence, the H C F required $=3\times 2^2\times x^3=12x^3$

Note *After exhibiting each expression as a product of powers of different elementary factors, the elementary factors* **common** *to the given expressions are at once obtained by writing down in succession such of the elementary factors of the first expression as are also found in* **every** *one of the remaining expressions Thus in the above example the elementary factors of the first expression are 3, 2, a, b, x and y, of which 3, 2 and x only are to be found in* **each** *of the others,*

EXERCISE 51.

Find the H C F of

1. a^2b^3 and a^3b^2 **2.** $12a^3b$ and $20a^2c^3$

3. $9xy^2z^3$ and $24x^3y^4$ **4.** $20a^3x^4y^5$ and $75a^2y^3$

5. $18m^2n^4$ and $45m^5n^3$ **6.** $16a^3x^4y$, $40a^2y^3x$ and $28x^3a$

7. $24m^2np^5$, $60mn^2p$ and $84m^3p^2$

8. $45x^3y^2z^4$, $75x^2y^4z^3$ and $90x^4y^3z^2$

9. $36a^2b^2c^4x^5$, $54a^5c^2x^4$ and $90a^4b^3c^5$

10. $72a^3b^4c^5$, $96b^3c^4d^5$ and $120c^3d^4a^5$

11. $48a^5x^4y^3z^2$, $60x^5y^4z^3b^2$ $72y^5z^4b^3a^2$ and $84z^5b^4a^3x^2$

12. $75m^4n^3p^5q^6$, $90m^3n^5p^6q^4$, $105m^6n^4p^3q^5$ and $135m^5n^6p^4q^3$

13. $54a^2b^5c^3d^4$, $72a^5b^2c^4d^3$, $108a^3b^4c^5d^2$ and $126a^4b^3c^2d^5$

14. $18a^3x^4y^5$. $42a^4y^3z^4$, $60x^3y^4z^5$ and $78a^2x^4z^3$

15. $32a^2b^3x^4y^5z^6$ $40a^3x^5y^4z^8$ $56b^3x^2y^7z^4$, $72x^6a^5y^2z^3$ and $96b^4a^8x^3y^3$

102. Highest Common Factors of compound expressions whose elementary factors can be easily found.

The method illustrated in the last article will also evidently apply in such cases

Example 1. Find the H C F of $a^3b^2+2a^2b^3$ and $a^5b-4a^3b^3$

$$a^3b^2+2a^2b^3=a^2b^2(a+2b),$$

$$\text{and } a^5b-4a^3b^3=a^3b(a^2-4b^2)=a^3b(a+2b)(a-2b)$$

Hence, the reqd H C F $=a^2b(a+2b)$

Example 2. Find the H C F of

$$x^4y^2+xy^5 \text{ and } x^4y+2x^3y^2+x^2y^3$$

$$x^4y^2+xy^5=xy^2(x^3+y^3)=xy^2(x+y)(x^2-xy+y^2)$$

$$\text{and } x^4y+2x^3y^2+x^2y^3=x^2y(x^2+2xy+y^2)=x^2y(x+y)^2$$

Hence, the reqd H C F. $=xy(x+y)$

Example 3. Find the H C F of

$$24(x^4-2ax^3-8a^2x^2) \text{ and } 54(x^5-ax^4-6a^2x^3)$$

The first expression $=3\times 8\times x^2(x^2-2ax-8a^2)$

$=3\times 2^3\times x^2(x+2a)(x-4a)$

The second expression $=6\times 9\times x^3(x^2-ax-6a^2)$

$=2\times 3^3\times x^3(x+2a)(x-3a)$.

Hence the required H C F $=3\times 2\times x^2(x+2a)$

$=6x^2(x+2a)$

Example 4. Find the H C F of

$$a^4-16x^4 \text{ and } a^3+a^2x-10ax^2+8x^3$$

The first expression $=(a^2+4x^2)(a^2-4x^2)$

$=(a^2+4x^2)(a+2x)(a-2x)$

The second expression $=(a-2x)(a^2+3ax-4x^2)$

$=(a-2x)(a-x)(a+4x)$

Hence the required H C F $=a-2x$

Note *It may be observed in this example that although the factors of the second expression are not so obvious as those of the first, still there is no great difficulty in discovering them as it may be presumed that the given expressions have at least one common factor Hence after the resolution of the first expression into factors, by a little trial it may be seen that of these $a-2x$ is also a factor of the second expression, thus the factorisation of the expression is much facilitated*

EXERCISE 52.

Find the H C F of

1. a^3-ab^2 and $a^4+2a^3b+a^2b^2$
2. $x^5y^3-x^3y^5$ and $x^5y^4+x^4y^5$
3. $6(x^2-9)$ and $15(x^3+27)$
4. $12(a^6-a^2b^2c^2)$ and $20(a^4b^2c^2+a^2b^3c^3)$
5. $m^6n^3-2m^5n^4+m^4n^5$ and $(m^2n-mn^2)^3$
6. $4a^4x-9a^2x^3$ and $4a^2x^2+6ax^3$
7. $18a^4b^3-32a^2b^5$ and $18a^4b^2+24a^3b^3$
8. $9x^4y^4-36x^2y^6$ and $24x^4y^2-48x^3y^3$
9. $6a^3b^2-24ab^4$ and $4a^5b+32a^2b^4$
10. $18x^2a^2(x+a)^2(x^2a^2-xa^3)$

 and $64(x^5a^2-x^2a^5)(x^3a+x^2a^2)$.

11. $24(x^3-a^3)$ and $40(x^4+x^2a^2+a^4)$

12. $56(x^6a^2-x^2a^6)$ and $72(x^5a^3+3a^5x^3+2a^7x)$

13. $30(a^2+4ab+3b^2)$ and $42(a^2+ab-6b^2)$

14. $28(x^3-3x^2-10x)$ and $52(x^4-8x^3+15x^2)$

15. $x^4y+3x^3y^2-18x^2y^3$ and $x^3y^2+10x^2y^3+24xy^4$

16. $a^4x^3-4a^3x^4-12a^2x^5$ and $a^5x^2+8a^4x^3+12a^3x^4$

17. $4x^3+12x^2+9x$ and $4x^2-2x-12$

18. $a^2-ab-2b^2$ and $a^3-a^2b-4ab^2+4b^3$

19. $x^2+3x-10$ and $x^3-x^2-14x+24$

20. $54(x^3+8a^3)$ and $90(x^3+7ax^2+16a^2x+12a^3)$

21. $(a^3-b^3)(a+b)^2$, a^4-b^4 and $3a^4+2a^3b-5a^2b^2$

22. $(2x-3)^2(x^2+x-2)$, $4x^2-x-18$ and $2x^2-23x-54$

23. $8(27a^5b+a^2b^4)$, $12(6a^4b^2-7a^3b^3-3a^2b^4)$ and $40(3a^3b^2+13a^2b^3+4ab^4)$

24. x^4-13x^2+36, $3x^3+13x^2+8x-12$ and $4x^3+17x^2+9x-18$

CHAPTER XV

LOWEST COMMON MULTIPLE

(by factorisation)

103. Definitions. One expression is said to be a *multiple* of another when the former is exactly divisible by the latter

One expression is said to be a *common multiple* of two or more others when it is exactly divisible by *each* of these latter

Of the different common multiples of two or more expressions that which consists of the *least* number of elementary factors is called the **Lowest Common Multiple** of those

expressions In other words, a common multiple of two or more expressions is said to be their *Lowest Common Multiple* when it is the product of *just* as many elementary factors as it *must necessarily* have and no more

Thus the common multiples of a and b are ab, $2ab$, a^2b, ab^2, a^2b^2, &c , but of these ab consists of the least number of elementary factors, and hence, it is called the lowest common multiple of the quantities a and b

Cor. Hence every common multiple of two or more expressions is divisible by their Lowest Common Multiple

Note *The letters L.C.M are usually written for "Lowest Common Multiple"*

104. L.C M. of simple expressions or such compound expressions as can be easily resolved into their elementary factors.

In such cases the L C M can be written down by inspection The following examples will illustrate the process

Example 1. Find the L.C M of $4a^2bc$ and $6ab^2d$

The 1st expression $=2^2\times a^2\times b\times c$

The 2nd expression $=2\times 3\times a\times b^2\times d$

Hence, $2^2\times 3\times a^2\times b^2\times c\times d$ *must necessarily* be a factor of *every* common multiple of them

Hence, the L C M required

$$=2^2\times 3\times a^2\times b^2\times c\times d$$
$$=12a^2b^2cd$$

Example 2. Find the L.C M of $24x^2yz$, $18xy^3z^2$ and $27x^4y^2z^2$

The 1st expression $=2^3\times 3\times x^2\times y\times z$

The 2nd expression $=2\times 3^2\times x\times y^3\times z^2$

The 3rd expression $=3^3\times x^4\times y^2\times z^2$.

Hence, $2^3\times 3^3\times x^4\times y^3\times z^2$ *must necessarily* be a factor of *every* common multiple of them

Hence, the L C M required

$$=2^3\times 3^3\times x^4\times y^3\times z^2$$
$$=216x^4y^3z^2.$$

Example 3. Find the L C M of

$$4x^2(x+a)^2,\ 6a^2x(x^2-a^2) \text{ and } 9x^3(x^3-a^3)$$

The 1st expression $=2^2\times x^2\times(x+a)^2$

The 2nd expression $=2\times 3\times a^2\times x\times(x+a)(x-a)$

The 3rd expression $=3^2\times x^3\times(x-a)(x^2+ax+a^2)$

Hence, $2^2\times 3^2\times a^2\times x^3\times(x+a)^2(x-a)(x^2+ax+a^2)$ *must necessarily* be a factor of *every* common multiple of them

Hence, the required L C M

$$=2^2\times 3^2\times a^2\times x^3\times(x+a)^2(x-a)(x^2+ax+a^2)$$
$$=36a^2x^3(x+a)^2(x^3-a^3)$$

Example 4. Find the L C M of

$$x^2-3x+2,\ x^3+2x^2-3x \text{ and } x^4+x^3-6x^2$$

The 1st expression $=(x-1)(x-2)$

The 2nd expression $=x(x^2+2x-3)=x(x-1)(x+3)$

The 3rd expression $=x^2(x^2+x-6)=x^2(x-2)(x+3)$

Hence, $x^2(x-1)(x-2)(x+3)$ *must necessarily* be a factor of *every* common multiple of the given expressions

Hence, the L C M required $=x^2(x-1)(x-2)(x+3)$

Example 5. Find the L C M of x^3-3x^2+3x-1, x^3-x^2-x+1, x^4-2x^3+2x-1 and $x^4-2x^3+2x^2-2x+1$

$$x^3-3x^2+3x-1=(x-1)^3$$

$$\begin{aligned}x^3-x^2-x+1&=x^2(x-1)-(x-1)\\&=(x-1)(x^2-1)=(x-1)^2(x+1)\end{aligned}$$

$$\begin{aligned}x^4-2x^3+2x-1&=(x^4-1)-2x(x^2-1)\\&=(x^2-1)\{(x^2+1)-2x\}\\&=(x^2-1)(x-1)^2\\&=(x-1)^3(x+1)\end{aligned}$$

$$\begin{aligned}x^4-2x^3+2x^2-2x+1&=x^2(x^2-2x+1)+(x^2-2x+1)\\&=(x^2-2x+1)(x^2+1)\\&=(x-1)^2(x^2+1)\end{aligned}$$

Hence, $(x-1)^3(x+1)(x^2+1)$ *must necessarily* be a factor of *every* common multiple of the given expressions

Hence, the L C M required $=(x-1)^3(x+1)(x^2+1)$

EXERCISE 53.

1. a^2b and ab^2 **2.** a^3b^2 and a^2bc

3. $6x^2y^4$ and $10xy^2$. **4.** $4m^2n^3$ and $14m^4n^2p$

5. $8x^2y^3z$ and $12x^3y^2z^2$ **6.** $4a^2bc$ $10ab^2c$ and $14abc^2$.

7. $8a^3b^2c$ $12ab^3c^2$ and $20a^2bc^3$

8. $6x^4y$, $9x^2y^2z$ $12a^2xy^3$ and $15axz^2$

9. a^3b-ab^3 and $a^3b^2+a^2b^3$

10. $4(x-y)^2$ $6(x^2-y^2)$ and $8(x+y)^2$

11. x^2-4x+3 and x^2-5x+6

12. $a^3+2a^2x-3ax^2$ and $a^4+a^3x-6a^2x^2$

13. $a^2(a^2-4)$ and $a^4+2a^3-8a^2$

14. $4a^2x^2$ $2x(x^2-a^2)$ and $6a^3x(x^3+a^3)$

15. $12(x^2+3x-10)$ and $16(x^2+4x-12)$

16. $x^2+2x-15$ $x^2+9x+20$ and $x^2+4x-21$

17. $12a^4-27a^2b^2$ $2a^2+ab-3b^2$ and $2a^2-ab-3b^2$

18. $8a^3+27b^3$, $8a^3-27b^3$ and $16a^4+36a^2b^2+81b^4$

19. $8x^4-50x^2y^2$ $12x^3+24x^2y-15xy^2$ and $16x^2-48xy+20y^2$.

20. $4x^2-12ax+9a^2$ $6x^2-7ax-3a^2$ and $6x^2-11ax+3a^2$

21. $2x^2-6x+9$ $4x^3-12x^2+18x$ and $4x^4+81$

22. $9a^2-6ax+x^2$. $6a^2+10ax-4x^2$ and $9a^2-21ax+6x^2$

23. $8x^3-12x^2+6x-1$ $8x^3-4x^2-2x+1$ and $2x^2+5x-3$

24. $x^2-6xy+8y^2$, $x^2-7xy+12y^2$, $x^2+2xy-15y^2$ and $x^2+xy-20y^2$.

25. $6x^2-x-1$ $3x^2+7x+2$ and $2x^2+3x-2$

[C U Entrance Paper, 1869]

26. $1+4x+4x^2-16x^4$ and $1+2x-8x^3-16x^4$

[C U Entrance Paper, 1871]

27. $9x^4-28x^2+3$ $27x^4-12x^2+1$ $27x^4+6x^2-1$ and x^4-6x^2+9

[C U Entrance Paper, 1886]

[The factors of the last expression suggest a factor of the first]

CHAPTER XVI

EASY FRACTIONS

105. Definition. The algebraical fraction $\frac{a}{b}$, where a and b may have *any* numerical values, is defined to be a quantity which, when multiplied by b, becomes equal to a In other words, $\frac{a}{b}$ is defined to be equivalent to $a \div b$ In $\frac{a}{b}$, a is called the **numerator** and b the **denominator.**

Note *Thus an **algebraical fraction** is no other than the quotient of one expression by another, **expressed by placing the dividend over the divisor with a horizontal line between them**; and the dividend and the divisor so placed are respectively called the **numerator** and the **denominator** of the fraction*

106. The value of a fraction is not altered if both its numerator and denominator are multiplied or divided by any the same quantity.

If a, b and m stand for any quantities whatever, to prove that

$$\frac{a}{b} = \frac{am}{bm}.$$

$$\text{Let} \qquad x = \frac{a}{b},$$

$$\text{then} \quad x \times b = \frac{a}{b} \times b = a \qquad \text{[by definition]};$$

$$\therefore \quad x \times b \times m = a \times m,$$

$$\text{or,} \quad x \times bm = am$$

$$\text{Hence,} \qquad x = am \div bm,$$

$$\text{i e} \qquad \frac{a}{b} = \frac{am}{bm}.$$

Conversely we have $\frac{am}{bm} = \frac{a}{b}$;

$$\text{i e,} \quad \frac{am}{bm} = \frac{am \div m}{bm \div m}.$$

Thus the proposition is established

Cor. $\frac{a}{b}=\frac{a\times(-1)}{b\times(-1)}=\frac{-a}{-b}$. Thus the value of a fraction is not altered if the signs of both the numerator and the denominator be changed

107. Reduction of a fraction to its lowest terms.

A fraction is said to be in its lowest terms, when its numerator and denominator have no common factor

Hence to reduce a fraction to its lowest terms, or more briefly to *simplify* it, is no other than to find an equivalent fraction whose numerator and denominator have no common factor, and this is evidently done by dividing the numerator and the denominator of the fraction by their highest common factor

Note *In all cases where the numerator and the denominator can be factorised by inspection the reduction is at once effected by simply removing the common factors*

Example 1. Reduce $\frac{4a^2b^3c^2}{10ab^4c^2}$ to its lowest terms

$$\frac{4a^2b^3c^2}{10ab^4c^2}=\frac{2\times2\times a^2\times b^3\times c^2}{2\times5\times a\times b^4\times c^2}=\frac{2a}{5b}.$$

Example 2. Simplify $\frac{a^2b^3(a^2-b^2)}{3ab^4(a^3+b^3)}$.

$$\frac{a^2b^3(a^2-b^2)}{3ab^4(a^3+b^3)}=\frac{a^2b^3(a+b)(a-b)}{3ab^4(a+b)(a^2-ab+b^2)}$$

$$=\frac{a(a-b)}{3b(a^2-ab+b^2)}.$$

Example 3. Reduce $\frac{x^2+3x-40}{x^2+4x-32}$ to its lowest terms

The numerator $=(x+8)(x-5)$

The denominator $=(x+8)(x-4)$

Hence, the given fraction $=\frac{(x+8)(x-5)}{(x+8)(x-4)}=\frac{x-5}{x-4}$.

Example 4. Simplify $\frac{2a^2+3ax-2ab-3bx}{3a^2-2ax-3ab+2bx}$.

The numerator $=2a(a-b)+3x(a-b)$

$=(a-b)(2a+3x)$

The denominator $=3a(a-b)-2x(a-b)$

$=(a-b)(3a-2x)$

Hence, the given expression $=\dfrac{(a-b)(2a+3x)}{(a-b)(3a-2x)}=\dfrac{2a+3x}{3a-2x}$.

EXERCISE 54.

Reduce to lowest terms

1. $\dfrac{2a^2b^3}{4a^2b^4}$.
2. $\dfrac{6x^2y^3}{8xy^4}$.
3. $\dfrac{4a^2xy^2}{10ax^2y^2}$.
4. $\dfrac{15x^3y^2z^4}{25x^2y^4z^3}$.
5. $\dfrac{18a^2bc^4d^5}{27a^3b^2c^4d^4}$.
6. $\dfrac{16x^2a^4y^3z^5}{40a^3z^4x^3y^4}$.
7. $\dfrac{70a^2b^3c^4d^7}{105c^4d^2a^3b^3}$.
8. $\dfrac{39m^2n^5p^3q^6}{65p^2m^3n^4q^5}$.
9. $\dfrac{x^2-a^2}{x^2+ax}$.
10. $\dfrac{x^2-3x}{9x-x^3}$.
11. $\dfrac{4x^2-9a^2}{4x^2+6ax}$.
12. $\dfrac{3a^2-12ab}{48b^2-3a^2}$.
13. $\dfrac{3ax-12a^2}{x^2-16a^2}$.
14. $\dfrac{2x^4-4a^2x^2}{x^4-4a^2x^2+4a^4}$.
15. $\dfrac{4x^2+8x}{x^2+5x+6}$
16. $\dfrac{x^2+2x-8}{x^2+x-12}$.
17. $\dfrac{x^2+2x-15}{x^2+9x+20}$.
18. $\dfrac{a^2-3ab-4b^2}{a^2-4ab-5b^2}$.
19. $\dfrac{a^4-a^3b+a^2b^2}{a^3+b^3}$.
20. $\dfrac{1-7x+12x^2}{1-8x+15x^2}$.
21. $\dfrac{x^2-6xy+5y^2}{x^2+2xy-35y^2}$.
22. $\dfrac{1-9a^2+14a^4}{1-4a^2-21a^4}$.
23. $\dfrac{x^4-8x^2-65}{x^4+x^2-20}$.
24. $\dfrac{3a^3x+9a^2x^2+27ax^3}{a^3-27x^3}$.
25. $\dfrac{2x^2-x-6}{3x^2-2x-8}$.
26. $\dfrac{3x^2-5ax+2a^2}{3x^2+ax-2a^2}$.
27. $\dfrac{3x^2+16ax+5a^2}{3x^2+22ax+7a^2}$.
28. $\dfrac{6x^2-7x-20}{9x^2+6x-8}$.
29. $\dfrac{2x^2+3ax-20a^2}{3x^2+5ax-28a^2}$.
30. $\dfrac{10-17ax+3a^2x^2}{5-26ax+5a^2x^2}$.
31. $\dfrac{x^2-(a-b)x-ab}{x^3+bx^2+ax+ab}$.
32. $\dfrac{6ac+10bc+9ax+15bx}{6c^2+9cx-2c-3x}$.
33. $\dfrac{8bx+12ab+6xy+9ay}{12bx+8ab+9xy+6ay}$.
34. $\dfrac{2a^2+ab-b^2}{a^3+a^2b-a-b}$.
35. $\dfrac{a^2-b^2-2bc-c^2}{a^2+2ab+b^2-c^2}$.

108. Reduction of two or more fractions to a common denominator.

Let $\frac{a}{b}$, $\frac{c}{d}$, $\frac{e}{f}$, &c, stand for any number of fractions

Let L denote the L C M of the denominators, i e, of b, d, f, &c Then, since the value of a fraction is not altered when its numerator and denominator are *both* multiplied by the same quantity, we must have

$$\frac{a}{b}=\frac{a\times(L\div b)}{b\times(L\div b)}=\frac{a\times(L\div b)}{L};$$

$$\frac{c}{d}=\frac{c\times(L\div d)}{d\times(L\div d)}=\frac{c\times(L\div d)}{L};$$

$$\frac{e}{f}=\frac{e\times(L\div f)}{f\times(L\div f)}=\frac{e\times(L\div f)}{L};$$

and so on

Thus the fractions in the third column are respectively equivalent to the given fractions and they have all got the same denominator, namely, L

Hence, we have the following rule for reducing fractions to a common denominator *Find the L C M of the denominators and multiply the numerators and denominators of each fraction by the quotient of the L C M, thus found, by the denominator of that fraction*

Example 1. Reduce $\frac{x}{a+b}$, $\frac{x^2}{a(a-b)}$ and $\frac{x^3}{b(a^2-b^2)}$ to a common denominator

The L C M of the denominators $=ab(a^2-b^2)$, and the quotients obtained by dividing it by the denominators are respectively $ab(a-b)$, $b(a+b)$ and a

Hence, we have $\frac{x}{a+b}=\frac{x\times ab(a-b)}{(a+b)\times ab(a-b)}=\frac{xab(a-b)}{ab(a^2-b^2)}$,

$$\frac{x^2}{a(a-b)}=\frac{x^2\times b(a+b)}{a(a-b)\times b(a+b)}=\frac{x^2b(a+b)}{ab(a^2-b^2)};$$

$$\frac{x^3}{b(a^2-b^2)}=\frac{x^3\times a}{b(a^2-b^2)\times a}=\frac{x^3a}{ab(a^2-b^2)}.$$

Example 2. Reduce $\frac{x-1}{x^2-5x+6}$, $\frac{x-2}{x^2-4x+3}$ and $\frac{x-3}{x^2-3x+2}$ to a common denominator

The denominators are respectively

$$(x-2)(x-3),\ (x-1)(x-3) \text{ and } (x-1)(x-2)$$

Hence, their L C M $=(x-1)(x-2)(x-3)$, and the quotients obtained by dividing it by the denominators are respectively, $x-1$, $x-2$ and $x-3$ Hence, we have

$$\frac{x-1}{x^2-5x+6}=\frac{(x-1)(x-1)}{(x^2-5x+6)(x-1)}=\frac{x^2-2x+1}{x^3-6x^2+11x-6};$$

$$\frac{x-2}{x^2-4x+3}=\frac{(x-2)(x-2)}{(x^2-4x+3)(x-2)}=\frac{x^2-4x+4}{x^3-6x^2+11x-6};$$

$$\frac{x-3}{x^2-3x+2}=\frac{(x-3)(x-3)}{(x^2-3x+2)(x-3)}=\frac{x^2-6x+9}{x^3-6x^2+11x-6}.$$

EXERCISE 55.

Reduce to a common denominator

1. $\frac{a}{2b}$, $\frac{3c}{4d}$ and $\frac{e}{f}$.

2. $\frac{x^2}{2bc}$, $\frac{y^2}{3ca}$, $\frac{z^2}{4ab}$.

3. $\frac{ab}{4xy^2}$, $\frac{bc}{6x^2y}$, $\frac{ca}{10x^3}$.

4. $\frac{a}{a-b}$, $\frac{b}{a+b}$, $\frac{c}{a(a+b)}$.

5. $\frac{x^2}{a^2+2ab}$, $\frac{y^2}{a-2b}$.

6. $\frac{2a}{a-b}$, $\frac{a-c}{ab-a^2}$.

7. $\frac{2a}{a-b}$, $\frac{3b}{b-a}$, $\frac{4c}{a+b}$.

8. $\frac{2x}{a^2(a+x)}$, $\frac{3y}{b^2(a-x)}$, $\frac{4z}{c^2(a^2-x^2)}$.

9. $\frac{a^2}{2xy-3y^2}$, $\frac{b^2}{2x^2+3xy}$, $\frac{c^2}{4x^3y-9xy^3}$.

10. $\frac{a^2}{x^2+x+1}$, $\frac{b^2}{x^2-x+1}$.

11. $\frac{3}{x^2-x-2}$, $\frac{4}{x^2+x-6}$.

12. $\dfrac{a-2b}{a(a^2-2ab+4b^2)}$, $\dfrac{bc}{a^3+8b^3}$.

13. $\dfrac{a}{a-3b}$, $\dfrac{b}{a^2+3ab+9b^2}$, $\dfrac{c}{a^3-27b^3}$.

14. $\dfrac{a}{b(a-b-c)}$, $\dfrac{b}{a(a-b+c)}$, $\dfrac{c}{a^2+b^2-c^2-2ab}$.

15. $\dfrac{c-a}{(a-b)(b-c)}$, $\dfrac{b-a}{(a-c)(b-c)}$, $\dfrac{b-c}{(c-a)(a-b)}$.

109. Addition of Fractions.

From Cor 3, Art 47, we know that

$a(b+c+d+e)=ab+ac+ad+ae$, where a, b, c, d, e are any quantities whatever Hence, conversely

$$\frac{ab+ac+ad+ae}{a}=b+c+d+e=\frac{ab}{a}+\frac{ac}{a}+\frac{ad}{a}+\frac{ae}{a}.$$

Hence, putting p, q, r, s respectively for ab. ac, ad, ae, we have

$$\frac{p+q+r+s}{a}=\frac{p}{a}+\frac{q}{a}+\frac{r}{a}+\frac{s}{a},$$ where p, q, r, s and a are any quantities whatever

Thus the sum of any number of fractions which have a common denominator is a fraction whose denominator is the same and whose numerator is the sum of the numerators of the given fractions

Hence, to obtain the sum of any number of fractions which have not the same denominator we must first reduce them to equivalent fractions having a common denominator and then proceed as above

Example 1. Find the value of $\dfrac{a}{a-b}+\dfrac{b}{b-a}$.

Since $\dfrac{b}{b-a}=\dfrac{b\times(-1)}{(b-a)\times(-1)}=\dfrac{-b}{a-b}$,

we have $\dfrac{a}{a-b}+\dfrac{b}{b-a}=\dfrac{a}{a-b}+\dfrac{-b}{a-b}$

$$=\frac{a+(-b)}{a-b}=\frac{a-b}{a-b}=1$$

Example 2. Find the value of $\frac{x}{x+a}+\frac{a}{x-a}$.

Since the L C M of the denominators $=x^2-a^2$,

we have $\frac{x}{x+a}=\frac{x(x-a)}{x^2-a^2}$ and $\frac{a}{x-a}=\frac{a(x+a)}{x^2-a^2}$.

Hence, the required value $=\frac{x(x-a)}{x^2-a^2}+\frac{a(x+a)}{x^2-a^2}$

$$=\frac{x(x-a)+a(x+a)}{x^2-a^2}$$

$$=\frac{x^2+a^2}{x^2-a^2}.$$

Example 3. Find the value of $\frac{1}{a+b}+\frac{b}{a^2-b^2}-\frac{a}{a^2+b^2}$.

In the present example it is not convenient to reduce all the fractions to a common denominator at once We can proceed best as follows

We have $\frac{1}{a+b}+\frac{1}{a^2-b^2}=\frac{(a-b)+b}{a^2-b^2}=\frac{a}{a^2-b^2}$.

Hence, the required value $=\frac{a}{a^2-b^2}-\frac{a}{a^2+b^2}$

$$=\frac{a(a^2+b^2)-a(a^2-b^2)}{a^4-b^4}$$

$$=\frac{2ab^2}{a^4-b^4}.$$

Example 4. Simplify $\frac{1}{x-2}-\frac{1}{x+2}-\frac{4}{x^2+4}+\frac{32}{x^4+16}$.

We have $\frac{1}{x-2}-\frac{1}{x+2}=\frac{(x+2)-(x-2)}{x^2-4}=\frac{4}{x^2-4}$;

$$\frac{4}{x^2-4}-\frac{4}{x^2+4}=\frac{4(x^2+4)-4(x^2-4)}{x^4-16}=\frac{32}{x^4-16}.$$

Lastly, $\frac{32}{x^4-16}+\frac{32}{x^4+16}=\frac{32(x^4+16)+32(x^4-16)}{x^8-256}$

$=\frac{64x^4}{x^8-256}$, which is the reqd result

Example 5. Simplify $\frac{1}{a+b}-\frac{1}{a+2b}-\frac{1}{a+3b}+\frac{1}{a+4b}$.

The given expression

$$=\left\{\frac{1}{a+b}-\frac{1}{a+2b}\right\}-\left\{\frac{1}{a+3b}-\frac{1}{a+4b}\right\}.$$

Now, we have

$$\frac{1}{a+b}-\frac{1}{a+2b}=\frac{(a+2b)-(a+b)}{(a+b)(a+2b)}$$

$$=\frac{b}{(a+b)(a+2b)},$$

and $\frac{1}{a+3b}-\frac{1}{a+4b}=\frac{(a+4b)-(a+3b)}{(a+3b)(a+4b)}=\frac{b}{(a+3b)(a+4b)}$

Lastly, $\frac{b}{(a+b)(a+2b)}-\frac{b}{(a+3b)(a+4b)}$

$$=\frac{b(a+3b)(a+4b)-b(a+b)(a+2b)}{(a+b)(a+2b)(a+3b)(a+4b)},$$

of which the numerator $=b(a^2+7ab+12b^2)-b(a^2+3ab+2b^2)$

$$=b(4ab+10b^2)=2b^2(2a+5b)$$

Hence, the reqd result $=\frac{2b^2(2a+5b)}{(a+b)(a+2b)(a+3b)(a+4b)}$.

EXERCISE 56.

Find the value of

1. $\frac{a+b}{a}+\frac{a-b}{b}$.
2. $\frac{x-y}{xy}+\frac{y-z}{yz}+\frac{z-x}{zx}$.
3. $\frac{a}{a-x}+\frac{x}{x-a}$.
4. $\frac{a+b}{a-b}-\frac{a-b}{a+b}$.
5. $\frac{a^2+b^2}{a^2-b^2}-\frac{a-b}{2(a+b)}$.
6. $\frac{4x^2+9y^2}{4x^2-9y^2}-\frac{2x-3y}{2x+3y}$
7. $\frac{a}{(a+b)^2}-\frac{b}{a^2-b^2}$.
8. $\frac{a^2+ab+b^2}{a+b}+\frac{a^2-ab+b^2}{a-b}$.
9. $\frac{1}{(a-b)(a-c)}+\frac{1}{(a-c)(b-c)}$.
10. $\frac{1}{x^2-3x+2}+\frac{1}{x^2-5x+6}$.

11. $\dfrac{1}{x^2+7x+10}+\dfrac{1}{x^2+13x+40}.$ **12.** $\dfrac{1}{2x+3y}-\dfrac{(2x-3y)^2}{8x^3+27y^3}.$

13. $\dfrac{a+b}{a-b}-\dfrac{a-b}{a+b}+\dfrac{2ab}{b^2-a^2}.$ **14.** $\dfrac{1}{a+2b}+\dfrac{1}{a-2b}+\dfrac{2a}{4b^2-a^2}.$

15. $\dfrac{x+y}{x-y}+\dfrac{x-y}{x+y}-\dfrac{2(x^2-y^2)}{x^2+y^2}.$ **16.** $\dfrac{a-2x}{a+2x}-\dfrac{a+2x}{a-2x}+\dfrac{8ax}{a^2+4x^2}.$

17. $\dfrac{3x+1}{x-3}-\dfrac{x-3}{3x+9}-\dfrac{5x^2+24x}{2x^2-18}.$

18. $\dfrac{4a-b}{1-4ab}-\dfrac{4a+b}{1+4ab}-\dfrac{4b(1-8a^2)}{16a^2b^2-1}.$

19. $\dfrac{x}{x-2a}+\dfrac{x}{x+2a}+\dfrac{2x^2}{x^2+4a^2}.$

20. $\dfrac{b}{a-b}+\dfrac{b}{a+b}+\dfrac{2ab}{a^2+b^2}+\dfrac{4a^3b}{a^4+b^4}.$

21. $\dfrac{x}{3x-y}+\dfrac{x}{3x+y}+\dfrac{6x^2}{9x^2+y^2}.$

22. $\dfrac{1}{x-3a}-\dfrac{1}{2x+6a}-\dfrac{x-9a}{2x^2+18a^2}.$

23. $\dfrac{(a^2+b^2)^2}{ab(a-b)^2}-\dfrac{a}{b}-\dfrac{b}{a}-2$

24. $\dfrac{1}{x-1}-\dfrac{1}{x+1}+\dfrac{1}{x-2}-\dfrac{1}{x+2}.$

25. $\dfrac{1}{x-a}-\dfrac{2}{2x+a}+\dfrac{1}{x+a}-\dfrac{2}{2x-a}.$

26. $\dfrac{3}{a-x}-\dfrac{1}{x+3a}+\dfrac{3}{a+x}+\dfrac{1}{x-3a}.$

27. $\dfrac{2}{x-1}-\dfrac{x}{x^2+1}-\dfrac{1}{x+1}-\dfrac{3}{1-x^2}.$

28. $\dfrac{a-c}{(a-b)(x-a)}+\dfrac{b-c}{(b-a)(x-b)}.$

29. $\dfrac{1}{x^2-3x+2}+\dfrac{1}{x^2-5x+6}+\dfrac{2}{x^2-8x+15}.$

30. $\dfrac{1}{x^2+5ax+4a^2}+\dfrac{1}{x^2+11ax+28a^2}+\dfrac{2}{x^2+20ax+91a^2}.$

31. $\dfrac{1}{x^2+3x+2}+\dfrac{2x}{x^2+4x+3}+\dfrac{1}{x^2+5x+6}.$

32. $\dfrac{1}{1-x+x^2}-\dfrac{1}{1+x+x^2}-\dfrac{2x}{1+x^2+x^4}.$

33. $\frac{1}{1+x+x^2}-\frac{1}{1-x+x^2}+\frac{2x}{1-x^2+x^4}$.

34. $\frac{1}{x-2}-\frac{x-2}{x^2+2x+4}+\frac{6x}{x^3+8}$.

35. $\frac{11}{16(2x^2-6ax+9a^2)}-\frac{11}{32x^2+96ax+144a^2}+\frac{33ax}{4(4x^4-81a^4)}$.

110. Multiplication of Fractions.

Let $\frac{a}{b}$ and $\frac{c}{d}$ be any two fractions, to find the value of $\frac{a}{b}\times\frac{c}{d}$.

Let $x=\frac{a}{b}\times\frac{c}{d}$

Then we have $x\times b\times d=\frac{a}{b}\times\frac{c}{d}\times b\times d$

$$=\frac{a}{b}\times b\times\frac{c}{d}\times d$$

$$=\left(\frac{a}{b}\times b\right)\times\left(\frac{c}{d}\times d\right)$$

$$=a\times c,$$

or, $x\times bd=ac$,

$\therefore$ $x=\frac{ac}{bd}$,

i e, $\frac{a}{b}\times\frac{c}{d}=\frac{ac}{bd}$.

Hence, $\frac{a}{b}\times\frac{c}{d}\times\frac{e}{f}=\frac{ac}{bd}\times\frac{e}{f}=\frac{ace}{bdf}$;

$\frac{a}{b}\times\frac{c}{d}\times\frac{e}{f}\times\frac{g}{h}=\frac{ace}{bdf}\times\frac{g}{h}=\frac{aceg}{bdfh}$; and so on

Thus, *the product of any number of fractions is a fraction whose numerator is the product of the numerators of the given fractions and whose denominator is the product of their denominators*

Cor. Since $c=\frac{c}{1}$, we have $\frac{a}{b}\times c=\frac{a}{b}\times\frac{c}{1}=\frac{ac}{b}$.

Example 1. Multiply together $\frac{x^2}{yz}$, $\frac{y^2}{zx}$ and $\frac{z^2}{xy}$.

The required product$=\frac{x^2\times y^2\times z^2}{yz\times zx\times xy}=\frac{x^2\times y^2\times z^2}{y^2\times z^2\times x^2}=1$

Example 2. Multiply $\frac{x(a-x)}{a^2+2ax+x^2}$ by $\frac{a(a+x)}{a^2-2ax+x^2}$

The required product $=\frac{x(a-x)\times a(a+x)}{(a^2+2ax+x^2)(a^2-2ax+x^2)}$

$$=\frac{ax(a-x)(a+x)}{(a+x)^2(a-x)^2}$$

$$=\frac{ax}{(a+x)(a-x)}=\frac{ax}{a^2-x^2}.$$

Example 3. Multiply together

$$\frac{1-x^2}{1+y},\ \frac{1-y^2}{x+x^2}\text{ and }1+\frac{x}{1-x}.$$

Since $\quad 1+\frac{x}{1-x}=\frac{1-x+x}{1-x}=\frac{1}{1-x}$,

the required product$=\frac{(1+x)(1-x)}{1+y}\times\frac{(1+y)(1-y)}{x(1+x)}\times\frac{1}{1-x}$

$$=\frac{(1+x)(1-x)(1+y)(1-y)}{(1+y)x(1+x)(1-x)}=\frac{1-y}{x}.$$

EXERCISE 57.

Multiply together.

1. $\frac{2a^2}{3ab}$, $\frac{9b^2}{16ac}$ and $\frac{8c^2}{9bc}$.

2. $\frac{4a^2b^2}{3c^2}$, $\frac{9c^2}{16d^2}$ and $\frac{4d^2}{27b^2}$.

3. $\frac{x^3}{yz}$, $\frac{y^3}{zx}$ and $\frac{z^3}{xy}$.

4. $\frac{7a^2b^2c^2}{12xyz}$ and $\frac{4x^3y^3z^3}{21a^4b^4c^4}$.

5. $\frac{12m^2n^3}{7xy^2z}$ and $\frac{35x^3yz}{96m^3n}$.

Simplify the following

6. $\frac{x+1}{x-1}\times\frac{x^2+x-2}{x^2+x}$.

7. $\frac{a^2-9b^2}{a^2+3ab}\times\frac{3a^2}{a^2-3ab}$.

8. $\dfrac{a^3-b^3}{a^2+ab}\times\dfrac{(a+b)^2}{a^2+ab+b^2}$. 9. $\dfrac{a^3+8x^3}{a^3-2a^2x}\times\dfrac{a^2-4ax+4x^2}{a^2-2ax+4x^2}$.

10. $\dfrac{x^2+4x+3}{x^2-4}\times\dfrac{x^2-3x+2}{x^2-9}$.

11. $\dfrac{x^2-7x+10}{x^2-2x-15}\times\dfrac{x^2-3x-18}{x^2-8x+12}$.

12. $\dfrac{x^2-4x+3}{x^2-6x+5}\times\dfrac{x^2-7x+10}{x^2-5x+6}$. 13. $\dfrac{a^4-b^4}{a^2-2ab+b^2}\times\dfrac{a-b}{a^2+ab}$.

14. $\dfrac{2x^2-5x+2}{3x^2-5x-2}\times\dfrac{3x^2+x}{4x-2}$.

15. $\dfrac{x^2-6x-16}{x^2-4x-21}\times\dfrac{x^2-11x+28}{x^2-12x+32}$.

16. $\dfrac{a^2-x^2}{a+b}\times\dfrac{a^2-b^2}{ax+x^2}\times\left(a+\dfrac{ax}{a-x}\right)$.

17. $\left(\dfrac{x^2}{a^2}-\dfrac{x}{a}+1\right)\left(\dfrac{x^2}{a^2}+\dfrac{x}{a}+1\right)$. 18. $\left(\dfrac{4a}{3x}+\dfrac{3x}{2b}\right)\left(\dfrac{2b}{3x}+\dfrac{3x}{4a}\right)$.

19. $\left(\dfrac{a}{b}+\dfrac{b}{a}\right)\left(\dfrac{c}{d}+\dfrac{d}{c}\right)-\left(\dfrac{a}{b}-\dfrac{b}{a}\right)\left(\dfrac{c}{d}-\dfrac{d}{c}\right)$.

20. $\dfrac{2x^2-7x+3}{2x^2+7x-4}\times\dfrac{3x^2+11x-4}{3x^2+8x-3}\times\dfrac{2x^2+x-15}{2x^2-11x+15}$.

21. $\dfrac{b^2-c^2-a^2+2ac}{c^2+a^2-b^2+2ac}\times\dfrac{b^2+c^2-a^2-2bc}{a^2-b^2+c^2-2ac}$.

22. $\dfrac{c^2-a^2-b^2+2ab}{b^2-c^2-a^2+2ac}\times\dfrac{a^2-b^2+c^2-2ac}{a^2+b^2-c^2-2ab}$.

111. Division of Fractions.

Let $\dfrac{a}{b}$ and $\dfrac{c}{d}$ be any two fractions, to find the value of $\dfrac{a}{b}\div\dfrac{c}{d}$.

Let $$x=\frac{a}{b}\div\frac{c}{d}.$$

Then we have $x\times\dfrac{c}{d}=\dfrac{a}{b}\div\dfrac{c}{d}\times\dfrac{c}{d}$

$$=\frac{a}{b} \qquad [\quad m \div n \times n = m, \text{ whatever } m \text{ and } n \text{ may be }]$$

$$\therefore \quad x \times \frac{c}{d} \times \frac{d}{c} = \frac{a}{b} \times \frac{d}{c};$$

$$\text{or,} \quad x = \frac{a}{b} \times \frac{d}{c}. \quad \left[\ \frac{c}{d} \times \frac{d}{c} = 1\ \right]$$

Thus, *to divide one fraction by another we have to multiply the former by the reciprocal of the latter.*

Cor. $\frac{a}{b} \div c = \frac{a}{b} \div \frac{c}{1} = \frac{a}{b} \times \frac{1}{c} = \frac{a}{bc}.$

Example 1. Simplify $\frac{a^3+b^3}{a^2-b^2} \div \frac{a^2-ab+b^2}{a-b}$.

$$\text{The required result} = \frac{a^3+b^3}{a^2-b^2} \times \frac{a-b}{a^2-ab+b^2}$$

$$= \frac{(a^3+b^3)(a-b)}{(a^2-b^2)(a^2-ab+b^2)}$$

$$= \frac{(a+b)(a^2-ab+b^2)(a-b)}{(a+b)(a-b)(a^2-ab+b^2)}$$

$$= 1$$

Example 2. Simplify

$$\frac{x^2+x-2}{x^2+7x+12} \div \frac{x^2-3x-10}{x^2+x-12} \times \frac{x^2-4x-5}{x^2-4x+3}.$$

The required result

$$= \frac{x^2+x-2}{x^2+7x+12} \times \frac{x^2+x-12}{x^2-3x-10} \times \frac{x^2-4x-5}{x^2-4x+3}$$

$$= \frac{(x-1)(x+2)}{(x+3)(x+4)} \times \frac{(x+4)(x-3)}{(x-5)(x+2)} \times \frac{(x-5)(x+1)}{(x-3)(x-1)}$$

$$= \frac{(x-1)(x+2)(x+4)(x-3)(x-5)(x+1)}{(x+3)(x+4)(x-5)(x+2)(x-3)(x-1)}$$

$$= \frac{x+1}{x+3}$$

Example 3. Simplify

$$\frac{\dfrac{a}{a-b}-\dfrac{a}{a+b}}{\dfrac{b}{a-b}-\dfrac{b}{a+b}} \div \frac{\dfrac{a+b}{a-b}+\dfrac{a-b}{a+b}}{\dfrac{a+b}{a-b}-\dfrac{a-b}{a+b}} \times \frac{a^2}{a^2+b^2}.$$

[Calcutta University Entrance Paper, 1876.]

We have $$\frac{\dfrac{a}{a-b}-\dfrac{a}{a+b}}{\dfrac{b}{a-b}-\dfrac{b}{a+b}} = \frac{\dfrac{a(a+b)-a(a-b)}{a^2-b^2}}{\dfrac{b(a+b)-b(a-b)}{a^2-b^2}}$$

$$=\frac{2ab}{a^2-b^2} \div \frac{2b^2}{a^2-b^2}$$

$$=\frac{2ab}{a^2-b^2} \times \frac{a^2-b^2}{2b^2}$$

$$=\frac{a}{b}, \qquad (1)$$

and $$\frac{\dfrac{a+b}{a-b}+\dfrac{a-b}{a+b}}{\dfrac{a+b}{a-b}-\dfrac{a-b}{a+b}} = \frac{\dfrac{(a+b)^2+(a-b)^2}{a^2-b^2}}{\dfrac{(a+b)^2-(a-b)^2}{a^2-b^2}}$$

$$=\frac{2(a^2+b^2)}{a^2-b^2} \div \frac{4ab}{a^2-b^2}$$

$$=\frac{2(a^2+b^2)}{a^2-b^2} \times \frac{a^2-b^2}{4ab}$$

$$=\frac{a^2+b^2}{2ab}. \qquad \ldots \quad (2)$$

Hence, from (1) and (2), the given expression

$$=\frac{a}{b} \div \frac{a^2+b^2}{2ab} \times \frac{a^2}{a^2+b^2}$$

$$=\frac{a}{b} \times \frac{2ab}{a^2+b^2} \times \frac{a^2}{a^2+b^2}$$

$$=\frac{2a^4}{(a^2+b^2)^2}.$$

EXERCISE 58.

Simplify

1. $\dfrac{4a^2bc}{15xy^2z} - \dfrac{8ab^2c}{25x^2yz}$.

2. $\dfrac{a^2+ab}{a-b} - \dfrac{ab}{a^2-b^2}$.

3. $\dfrac{x^2-49}{x^2-25} - \dfrac{x+7}{x+5}$.

4. $\dfrac{a^4-b^4}{a^2+2ab+b^2} - \dfrac{a^2+b^2}{a+b}$.

5. $\dfrac{m^2-9n^2}{m^2+5mn+6n^2} - \dfrac{m^2-2mn-3n^2}{m^2-n^2}$.

6. $\dfrac{m^3-n^3}{m+n} \div \dfrac{m^2+mn+n^2}{m^2-n^2}$.

7. $\left(\dfrac{2x+y}{x+y}-1\right) - \left(1-\dfrac{y}{x+y}\right)$.

8. $\left(\dfrac{a}{a+b}+\dfrac{b}{a-b}\right) - \left(\dfrac{a}{a-b}-\dfrac{b}{a+b}\right)$.

9. $\left(\dfrac{x+y}{x-y}+\dfrac{x-y}{x+y}\right) - \left(\dfrac{x+y}{x-y}-\dfrac{x-y}{x+y}\right)$.

10. $\dfrac{x^2-4}{x^2+3x-18} - \dfrac{x^2-5x-14}{x^2-36}$.

11. $\left\{1-\dfrac{2pq}{p^2+q^2}\right\} - \left\{\dfrac{p^3-q^3}{p-q}-3pq\right\}$.

12. $\dfrac{a^3+b^3+3ab(a+b)}{(a+b)^2-4ab} - \dfrac{(a-b)^2+4ab}{a^3-b^3-3ab(a-b)}$.

13. $\dfrac{x^3+y^3}{(x-y)^2+3xy} - \dfrac{(x+y)^2-3xy}{x^3-y^3} \times \dfrac{xy}{x^2-y^2}$.

14. $\dfrac{a(a-b)^2+4a^2b}{ab+b^2} \div \dfrac{a^2-b^2}{ab} \times \dfrac{b(a+b)^2-4ab^2}{a^2-ab}$.

15. $\dfrac{x^2-x-30}{x^2-36} - \dfrac{x^2+3x-10}{x^2+2x-8} \div \dfrac{x+4}{2x^2+12x}$.

16. $\dfrac{x^2+3x-108}{x^2-64} - \dfrac{x^2+6x-72}{x^2+x-56} - \dfrac{x^2-16x+63}{x^2-14x+48}$.

17. $\left(\dfrac{x^2+y^2}{x^2-y^2}+\dfrac{x^2-y^2}{x^2+y^2}\right) - \left(\dfrac{x+y}{x-y}-\dfrac{x-y}{x+y}\right)$.

18. $\left\{\dfrac{a+b}{a-b}+\dfrac{a^2+b^2}{a^2-b^2}\right\} \div \left\{\dfrac{a-b}{a+b}-\dfrac{a^3-b^3}{a^3+b^3}\right\}$. [C U 1868]

19. $\dfrac{a^4-b^4}{(a+b)^3-3ab(a+b)}-\dfrac{(a+b)^2-4ab}{(a+b)^2-3ab}\times\dfrac{a}{(a+b)^2-2ab}$.

20. $\dfrac{(a-b)\{(a+b)^2-ab\}}{(a-b)^2+2ab}-\dfrac{(a-b)^2+3ab}{(a+b)\{(a-b)^2+ab\}}\times\dfrac{(a+b)^2-2ab}{(a+b)^2-3ab}$.

21. $\dfrac{\dfrac{a^3}{b^3}-\dfrac{b^3}{a^3}}{\left(\dfrac{a}{b}-\dfrac{b}{a}\right)\left(\dfrac{a}{b}+\dfrac{b}{a}-1\right)}+\dfrac{\dfrac{1}{b}-\dfrac{1}{a}}{\dfrac{1}{a^2}+\dfrac{1}{b^2}+\dfrac{1}{ab}}$

[Calcutta University Entrance Paper, 1874]

CHAPTER XVII

SIMPLE EQUATIONS AND PROBLEMS

I. Simple Equations.

112. In Chapter V, we have explained the process of solving easy simple equations We propose to consider the subject more fully here

We have stated that the process of solving any equation is primarily based upon certain axioms [Art 63] from which it has been noticed that an equation is not altered,

(i) if any term be transposed from one side of the equation to the other, and (ii) if both the sides be multiplied or divided by any the *same* quantity

Hence, the general rule for solving a simple equation involving one unknown quantity may be put as follows

(1) *Simplify the two sides separately by clearing of fractions and brackets if any, and by performing operations indicated by the symbols*

(2) *Transpose all the terms involving the unknown quantity to the left-hand side of the equation and the remaining terms to the right-hand side*

(3) *Next, simplify the two sides again*

(4) *Finally divide both the sides by the co-efficient of the unknown quantity*

The value of the unknown quantity, thus obtained, is the required solution

Note *The student should verify for his own satisfaction that this value does really satisfy the given equation*

Example 1. $(6x+9)^2+(8x-7)^2=(10x+3)^2-71$

[C U Entrance Paper, 1882]

The left side $=(36x^2+108x+81)+(64x^2-112x+49)$

$=100x^2-4x+130$,

and the right side $=(100x^2+60x+9)-71$

$=100x^2+60x-62$

Hence, the equation stands thus

$$100x^2-4x+130=100x^2+60x-62$$

Removing $100x^2$ from both sides, we have

$$-4x+130=60x-62$$

Hence, by transposition,

$$-4x-60x=-130-62$$

or, $$-64x=-192$$

and therefore, dividing both sides, by -64, we have

$$x=3$$

Thus, the required root is 3

Example 2. Given $\frac{x-6}{8}-\frac{2x-15}{9}+1=\frac{x}{15}-\frac{x-12}{6}$; find x

Multiplying both sides by $8\times9\times5$ or 360, which is the L C M of the denominators, we have

$$\frac{360(x-6)}{8}-\frac{360(2x-15)}{9}+360=\frac{360x}{15}-\frac{360(x-12)}{6}$$

or, $$45(x-6)-40(2x-15)+360=24x-60(x-12)$$

or, $$45x-270-80x+600+360=24x-60x+720$$

or, $$-35x+690=-36x+720$$

Hence, by transposition, $-35x+36x=720-690$

or, $x=30$

Example 3. Solve $\frac{1}{3}\{4a(1+x)-\frac{9}{4}(a-x)\}=\frac{1}{4}\{3a(1-x)-\frac{16}{3}(a+x)\}$.

The left side $=\frac{4a}{3}(1+x)-\frac{3}{4}(a-x)\}=\left(\frac{4a}{3}-\frac{3a}{4}\right)+\left(\frac{4a}{3}+\frac{3}{4}\right)x$

$$=\frac{7a}{12}+\frac{16a+9}{12}x$$

and the right side

$$=\frac{3a}{4}(1-x)-\frac{4}{3}(a+x)$$

$$=\left(\frac{3a}{4}-\frac{4a}{3}\right)-\left(\frac{3a}{4}+\frac{4}{3}\right)x$$

$$=-\frac{7a}{12}-\frac{9a+16}{12}x$$

Hence, the equation stands thus

$$\frac{7a}{12}+\frac{16a+9}{12}x=-\frac{7a}{12}-\frac{9a+16}{12}x$$

Multiplying both sides by 12,

$$7a+(16a+9)x=-7a-(9a+16)x$$

Hence, by transposition,

$$\{(16a+9)+(9a+16)\}x=-14a$$

or, $25(a+1)x=-14a$

. dividing both sides by $25(a+1)$, we have

$x=\frac{-14a}{25(a+1)}$, which is the required root.

Example 4. Given $\frac{x}{a+b}+1=\frac{x}{a-b}+\frac{a-b}{a+b}$, find x

Multiplying both sides by a^2-b^2, which is the L C M of the denominators, we have

$$(a-b)x+(a^2-b^2)=(a+b)x+(a-b)^2$$

Hence, by transposition,

$$(a-b)x-(a+b)x=(a-b)^2-(a^2-b^2)$$

or, $$\{(a-b)-(a+b)\}x=-2ab+2b^2$$

or $$-2bx=-2b(a-b)$$

Therefore, dividing both sides by $-2b$, we have

$$x=a-b$$

EXERCISE 59.

Find the value of x, when

1. $3(x-4)^2+5(x-3)^2=(2x-5)(4x-1)+24$

2. $(12x+9)^2+(5x+3)^2=(13x+9)^2+33$

3. $5(x+1)^2+7(x+3)^2=12(x+2)^2$

4. $(3x-14)^2+(4x-19)^2-(5x-23)^2=22$

5. $(5x-8)^2+(12x-7)^2=(13x-10)^2+37$

6. $(x-1)^3+(x+1)^3=2x(x^2-1)+4$

7. $(x-2)^3+2x^3+(x+2)^3=4x^2(x+2)$

8. $(x+2)(x+3)(x+4)+96=x^2(x+9)+5(3x+13)$

9. $3(x^2-14)=(x+1)^2+(x-2)^2+(x-5)^2$

10. $a(x-a)=b(x-b)$ **11.** $3(x-a)+5(2x-3a)=8a$

Solve the following equations

12. $(x+a)(x+b)-(a+b)^2=(x-a)(x-b)$

13. $a^2(x-a)+b^2(x-b)=abx$

14. $m^2(x-m)+n^2(x+n)+mnx=0$

15. $b(x-2a)+a(x-2b)=(a-b)^2$

16. $a(4x-a)+b(4x-b)-2ab=0$

17. $x(x-a)+x(x-b)-2(x-a)(x-b)=0$

18. $(x+3a)(x-3b)+3(x-3a)(x+3b)=4(x-3a)(x-3b)$

19. $(2b+2c-x)^2+(2b-2c+x)^2$
$$=(2b+2d-x)^2+(2b-2d+x)^2$$

20. $(x-a)^3+(x-b)^3+(x-c)^3=3(x-a)(x-b)(x-c)$

21. $(x+a)^3+(x+b)^3+(x+c)^3=3(x+a)(x+b)(x+c)$

22. $\frac{x}{a}+a=\frac{x}{b}+b$ **23.** $\frac{a}{bx}-\frac{b}{ax}=a^2-b^2$

24. $\frac{1}{2}(x+1)+\frac{1}{3}(x+2)+\frac{1}{4}(x+3)=16$

25. $\frac{x-6}{5}+\frac{x-4}{3}=8-\frac{x-2}{7}$. **26.** $\frac{x}{10}+\frac{2x-13}{9}=8-\frac{4x-35}{15}$.

27. $\frac{x+7}{2}+\frac{x+13}{5}+\frac{x+17}{7}=\frac{x+27}{4}$.

28. $6\frac{1}{3}-\frac{x-7}{3}=\frac{4x-2}{5}$. [C U Entr Paper, 1861]

29. $\frac{x-1}{3}-\frac{x-9}{2}+\frac{3x-2(x-2)}{7}=4\frac{1}{2}$

30. $\frac{2x-9}{27}+\frac{x}{18}-\frac{x-3}{4}=8\frac{1}{3}-x$ **31.** $\frac{9x+7}{2}-\left(x-\frac{x-2}{7}\right)=36$

32. $\frac{7x+9}{4}-\left(x-\frac{2x-1}{9}\right)=7$

33. $\frac{x+7}{3}-5\frac{3}{4}=\frac{2x+5}{7}+\frac{10-5x}{8}$.

34. $x-\left(3x-\frac{2x-5}{10}\right)=\frac{1}{6}\left(2x-57\right)-\frac{5}{3}$. [C U 1889]

35. $\frac{4x-21}{7}+7\frac{5}{6}+\frac{7x-23}{3}=x+3\frac{3}{4}-\frac{9-7x}{8}+\frac{1}{12}$.

36. $\frac{1}{2}\left(x-\frac{a}{3}\right)-\frac{1}{3}\left(x-\frac{a}{4}\right)+\frac{1}{4}\left(x-\frac{a}{5}\right)=0$ [C U 1866]

37. $\frac{x-3}{7}-\frac{\frac{1}{2}x-3}{3}=\frac{\frac{1}{6}x+2}{2}-\frac{x-6}{3}+\frac{x}{8}$. [C U 1866]

38. $\frac{1}{8}(x-2)-\frac{1}{7}(x-4)=\frac{1}{12}(2x-3)-2\frac{3}{4}$ [C U 1869]

39. $\frac{a-x}{a}+\frac{2a-x}{2a}=\frac{3a-x}{3a}$. [C U Entr Paper, 1870]

40. $\frac{2x-13}{9}-\frac{x-1}{11}=\frac{x}{8}+\frac{x}{7}-9$ [C U Entr. Paper, 1876]

41. $\frac{2x-3}{6}+\frac{3x-8}{11}=\frac{4x+15}{33}+\frac{1}{2}$. [C U Entr Paper 1877]

42. $\dfrac{4x+3}{9}+\dfrac{13x}{108}=\dfrac{8x+19}{18}$. [C U Entr Paper, 1878]

43. $\dfrac{x^2-2\frac{1}{2}}{4}-\dfrac{x-3\frac{1}{2}}{5}=\dfrac{2x^2-3}{8}-\dfrac{x-5\frac{1}{2}}{3}$.

[C U Entr Paper, 1883]

44. $\dfrac{a-x^2}{bx}-\dfrac{b-x}{c}=\dfrac{c-x}{b}-\dfrac{b-x^2}{cx}$. [C U Entr Paper, 1886]

45. $\dfrac{x+2\frac{1}{2}}{15}+\dfrac{x+3\frac{1}{3}}{25}=\dfrac{x+4\frac{1}{6}}{55}$. [C U Entr Paper, 1888]

46. $\dfrac{11x-13}{25}+\dfrac{19x+3}{7}-\dfrac{5x-25\frac{1}{3}}{4}=28\frac{1}{7}-\dfrac{17x+4}{21}$.

47. $\dfrac{x-1\frac{25}{26}}{2}-\dfrac{2-6x}{13}=x-\dfrac{5x-\frac{1}{4}(10-3x)}{39}$.

48. $\dfrac{3x-\frac{2}{3}(1+x)}{4}+\dfrac{1-\frac{1}{5}x}{5\frac{1}{2}}=\dfrac{2\frac{2}{5}+\frac{1}{25}(x-1)}{2\frac{1}{5}}$.

49. $\frac{1}{3}(x-a)-\frac{1}{5}(2x-3b)-\frac{1}{2}(a-x)=10a+11b$

50. $\dfrac{2x+a}{b}-\dfrac{x-b}{a}=\dfrac{3ax+(a-b)^2}{ab}$.

51. $\dfrac{2x+1}{29}-\dfrac{402-3x}{12}=9-\dfrac{471-6x}{2}$.

52. $\dfrac{15-\frac{2}{3}x}{5}-\dfrac{2x+5}{2\frac{1}{2}}=\dfrac{17-\frac{14}{3}x}{3}$. [C U Entr Paper, 1874]

113. Equations involving Decimals.

The decimals, if necessary, may be converted into vulgar fractions

Example 1. Solve $\dfrac{x-2}{05}-\dfrac{x-4}{0625}=56$

Since, $05=\dfrac{5}{90}=\dfrac{1}{18}$ and $0625=\dfrac{625}{10000}=\dfrac{1}{16}$,

we have $\dfrac{x-2}{\frac{1}{18}}-\dfrac{x-4}{\frac{1}{16}}=56$,

or, $18(x-2)-16(x-4)=56$,

or, $2x+28=56$,

$\therefore$ $2x=28$, or, $x=14$

Example 2. Solve $65x+\frac{585x-975}{6}=\frac{1\ 56}{2}-\frac{39x-78}{9}$.

Since $\frac{585x-975}{6}=\frac{5\ 85x-9\ 75}{6}=\frac{1\ 95x-3\ 25}{2}$,

$$\frac{1\ 56}{2}=\frac{15\ 6}{2}=7\ 8,$$

and $\frac{39x-78}{9}=\frac{3\ 9x-7\ 8}{9}=\frac{1\ 3x-2\ 6}{3}$,

the equation stands thus

$$65x+\frac{1\ 95x-3\ 25}{2}=7\ 8-\frac{1\ 3x-2\ 6}{3}.$$

Hence, multiplying both sides by 6, we have

$$3\ 9x+(5\ 85x-9\ 75)=46\ 8-(2\ 6x-5\ 2)$$

By transposition,

$$(3\ 9+5\ 85+2\ 6)x=46\ 8+5\ 2+9\ 75$$

or, $\quad 12\ 35x=61\ 75$

$$x=\frac{61\ 75}{12\ 35}=5$$

EXERCISE 60.

Solve the following equations

1. $5x-2x=3x-1\ 5$

2. $3\ 75x+5=2\ 25x+8$

3. $1\ 2x-\frac{18x-05}{5}=4x+8\ 9$

4. $\frac{x+75}{125}-\frac{x-25}{25}=15$

5. $\frac{x}{5}-\frac{1}{05}+\frac{x}{005}-\frac{1}{0005}=0$ [C U Entr Paper, 1883]

6. $5x+\frac{45x-75}{6}=\frac{1\ 2}{2}-\frac{3x-6}{9}$

7. $7x+4=67x+5$

8. $15x+\frac{135x-225}{6}=\frac{\cdot 36}{2}-\frac{09x-18}{9}$.

9. $5x+\frac{02x+07}{03}-\frac{x+2}{9}=9\ 5$

10. $011x+\frac{001x-125}{6}=\frac{5-x}{03}-145$

[C U Entr Paper, 1886]

114. Solution of equations facilitated by suitable transposition and combination of terms.

Example 1. Solve $\dfrac{23x-29}{12}+\dfrac{19x+13}{7}=\dfrac{97x+72\frac{1}{2}}{35}+\dfrac{7x-8\frac{1}{3}}{4}$.

By transposition, we have

$$\frac{23x-29}{12}-\frac{7x-8\frac{1}{3}}{4}=\frac{97x+72\frac{1}{2}}{35}-\frac{19x+13}{7};$$

or, $$\frac{(23x-29)-(21x-25)}{12}=\frac{(97x+72\frac{1}{2})-(95x+65)}{35},$$

or, $$\frac{x-2}{6}=\frac{2x+7\frac{1}{2}}{35}.$$

Hence, multiplying both sides by 6×35,

$$35x-70=12x+45$$

Hence, $23x=115$, or, $x=5$

Example 2. Solve $\dfrac{x-a(b+c)}{bc}+\dfrac{x-b(c+a)}{ca}+\dfrac{x-c(a+b)}{ab}=3$

The equation may be written as

$$\frac{x-a(b+c)}{bc}+\frac{x-b(c+a)}{ca}+\frac{x-c(a+b)}{ab}=1+1+1$$

By transposition, we have

$$\left\{\frac{x-a(b+c)}{bc}-1\right\}+\left\{\frac{x-b(c+a)}{ca}-1\right\}+\left\{\frac{x-c(a+b)}{ab}-1\right\}=0,$$

or, $$\frac{x-a(b+c)-bc}{bc}+\frac{x-b(c+a)-ca}{ca}+\frac{x-c(a+b)-ab}{ab}=0;$$

or, $$\frac{x-(ab+ac+bc)}{bc}+\frac{x-(ca+cb+ab)}{ca}+\frac{x-(ca+cb+ab)}{ab}=0,$$

or $$\left\{x-(ab+bc+ca)\right\}\left\{\frac{1}{bc}+\frac{1}{ca}+\frac{1}{ab}\right\}=0;$$

$$\therefore\ x-(ab+bc+ca)=0$$

Hence, $x=ab+bc+ca$

EXERCISE 61.

Solve the following equations

1. $\dfrac{5x+6}{4}+\dfrac{64x-35}{15}=\dfrac{20x+23}{16}+\dfrac{13x-7}{3}$.

2. $\dfrac{17x-13}{9}+\dfrac{108x+75}{32}=\dfrac{27x+19}{8}+\dfrac{50\frac{7}{16}x-39}{27}$.

3. $\dfrac{29x-18}{8}+\dfrac{189x-93}{49}=\dfrac{86\frac{13}{14}x-54}{24}+\dfrac{27x-13}{7}.$

4. $\dfrac{16x-17}{9}-\dfrac{23x-15}{16}=\dfrac{142\frac{7}{18}x-153}{81}-\dfrac{92x-65}{64}.$

5. $\dfrac{18x-19}{7}+\dfrac{135x+62\frac{1}{2}}{65}=\dfrac{27x+14}{13}+\dfrac{106\frac{5}{13}x-114}{42}.$

6. $\dfrac{33-19x}{15}-\dfrac{41+27x}{28}+\dfrac{164+107\frac{11}{15}x}{112}-\dfrac{164\frac{13}{28}-95x}{75}=0$

7. $\dfrac{18-41x}{9}-\dfrac{17-16x}{8}+\dfrac{9\frac{16}{21}-10x}{5}-\dfrac{14-32x}{7}=0$

8. $\dfrac{x-a^2}{b^2+c^2}+\dfrac{x-b^2}{c^2+a^2}+\dfrac{x-c^2}{a^2+b^2}=3$

9. $\dfrac{3x-bc}{b+c}+\dfrac{3x-ca}{c+a}+\dfrac{3x-ab}{a+b}=a+b+c$

10. $\dfrac{ax-b^2+c^2}{c-b}+\dfrac{bx-c^2+a^2}{a-c}+\dfrac{cx-a^2+b^2}{b-a}=2(a+b+c)$

11. $\dfrac{x-(b^3+c^3)}{a^2-3bc}+\dfrac{x-(c^3+a^3)}{b^2-3ca}+\dfrac{x-(a^3+b^3)}{c^2-3ab}=a+b+c$

12. $\dfrac{p^2x+(l^3+m^3)}{l^2-lm+m^2}+\dfrac{q^2x+(m^3+n^3)}{m^2-mn+n^2}+\dfrac{r^2x+(n^3+l^3)}{n^2-ln+l^2}$
$$=2(l+m+n)$$

II. Problems.

115. We have already explained in Chap VI how simple algebraical problems can be expressed symbolically and solved We proceed now to consider examples of a harder type

As pointed out before, the chief difficulty in the solution of a problem lies in constructing its symbolical expression The student should, therefore, become proficient in it by constant and varied practice

No general rule for solution can be stated The following advice can, however, be offered

Read the problems several times and consider its meaning carefully

See what quantity is required to be found out in the problem Represent it by x

Next express the conditions of the problem in terms of the symbol x and obtain a simple equation in x

Finally, solving this equation, find the value of x

The process is explained by the following examples For further illustrations, the student is referred to Chapter VI

Example 1. How old is a man now, who, 20 years ago, was five times as old as his son who will be 41 years old 16 years after ?

The present age of the man is to be found out Let it be x years

20 years ago, the man's age $=(x-20)$ years

16 years after the son's age will be 41 years ,

the son's present age $=41-16=25$ years

Hence, 20 years ago, the son's age $=25-20=5$ years

From the condition of the problem,

$$x-20=5\times 5,$$

or, $x=20+5\times 5=20+25=45$

Thus the man's present age $=45$ years

Example 2. The sum of five consecutive numbers is 1185. What are the numbers ?

Let $x=$ the smallest of the consecutive numbers Since consecutive numbers differ from each other by 1, the numbers after x are $x+1$, $x+2$, $x+3$, $x+4$, etc In the present problem, the consecutive numbers are therefore, x, $x+1$, $x+2$, $x+3$, $x+4$

By the condition of the problem, their sum $=1185$,

or, $x+(x+1)+(x+2)+(x+3)+(x+4)=1185,$

or, $5x+10=1185$

or, $5x=1185-10=1175$

$$x=\frac{1175}{5}=235$$

Thus, the smallest of the consecutive numbers is 235

Hence, the 5 consecutive numbers required are 235, 236, 237, 238, 239

Example 3. Two persons started at the same time from A One rode on horse back at the rate of $7\frac{1}{2}$ miles an hour and arrived at B 30 minutes latter than the other who travelled the same distance by train at the rate of 30 miles an hour Find the distance between A and B [C U Entr Paper, 1873]

Let x be the distance in miles between A and B Then the time taken by the first man to travel the distance $=\frac{x}{7\frac{1}{2}}$ hours$=\frac{2x}{15}$ hours and the time taken by the other$=\frac{x}{30}$ hours

But the time taken by the former is half an hour more than that taken by the latter

Hence, $$\frac{2x}{15}=\frac{x}{30}+\frac{1}{2},$$

or $$4x=x+15,$$

$$3x=15 \qquad x=5$$

Thus, the distance between A and $B=5$ miles

Example 4. A person being asked his age, replied, "Ten years ago I was 5 times as old as my son, but 20 years hence I shall be only twice as old as he" What is his age?

Let the present age of the person be x years

Then 10 years ago his age was $(x-10)$ years and $\therefore$ that of his son was $\frac{1}{5}(x-10)$ years

Hence, the present age of his son $\{\frac{1}{5}(x-10)+10\}$ years, and the son's age 20 years hence will be $\{\frac{1}{5}(x-10)+30\}$ years, and the age of the person 20 years hence will evidently be $(x+20)$ years

Hence, by the second condition of the problem, we must have $$x+20=2\{\tfrac{1}{5}(x-10)+30\}$$

$$=\tfrac{2}{5}(x-10)+60,$$

$$\therefore\ 5x+100=2x-20+300,$$

$$\therefore\ 3x=180, \qquad \therefore\ x=60$$

Note *Fractions might have been avoided by assuming the present age of the person to be 5x years The student can easily proceed on this assumption*

Example 5. A and B have the same annual income. A lays by a *fifth* of his, but B, by spending annually £80 more than A at the end of 4 years finds himself £220 in debt What was their income?

Let £x be the income of each.

Then A spends £$\frac{4}{5}x$ annually Hence, B spends annually £$(\frac{4}{5}x+80)$

But spending at this rate B contracts a debt of £220 in 4 years or a debt of £55 per year. His annual income therefore falls short of his annual expenses by £55.

Hence we must have $x = (\frac{4}{5}x + 80) - 55$

$$\therefore \quad \tfrac{1}{5}x = 25, \qquad \therefore \quad x = 125.$$

Thus A and B had each an income of £125.

Example 6. A market woman bought a certain number of eggs at 2 a penny, and as many at 3 a penny, and sold them at the rate of 5 for two pence, losing $4d$ by her bargain. What number of eggs did she buy?

Let x = the number of eggs bought.

Then since one half of them were bought at 2 a penny, and the other half at 3 a penny, the whole cost in buying the eggs

$$= \left(\frac{x}{2} \cdot \frac{1}{2} + \frac{x}{2} \cdot \frac{1}{3}\right) \text{ pence} = \left(\frac{x}{4} + \frac{x}{6}\right) \text{ pence.}$$

By selling the eggs at 5 for two pence, the amount realised $= x \times \frac{2}{5}$ pence.

Hence, by the question, $\dfrac{2x}{5} = \left(\dfrac{x}{4} + \dfrac{x}{6}\right) - 4$,

$$\text{or} \qquad 24x = 15x + 10x - 240, \qquad \therefore \quad x = 240.$$

Thus, altogether 240 eggs were bought.

Example 7. There is a number consisting of two digits, the digit in the unit's place is twice that in the ten's place, and if 2 be subtracted from the sum of the digits, the difference is equal to $\frac{1}{6}$th of the number. Find the number.

Let x = the digit in the ten's place.

Then $2x$ = " " " unit's "

Clearly therefore the number $= 10x + 2x$.

[See Example 4 worked out in Art 65.]

Hence, by the second condition of the problem,

$$\left(x + 2x\right) - 2 = \frac{10x + 2x}{6},$$

$$\text{whence,} \qquad 18x - 12 = 12x,$$

$$\text{or,} \qquad 6x = 12, \qquad \therefore \quad x = 2.$$

Hence, the required number = 24.

EXERCISE 62.

1. The length of a field is twice its breadth, another field which is 50 yds longer and 10 yds. broader, contains 6800 square yds more than the former, find the size of each

2. The length of a room exceeds its breadth by 3 feet, if the length had been increased by 3 feet, and the breadth diminished by 2 feet, the area would not have been altered, find the dimensions

3. A and B began to play with equal sums, and when B has lost $\frac{5}{11}$th of what he had to begin with, A has gained £6 more than half of what B has been left with, what had they at first?

4. The ages of a father and his son together are 80 years, and if the age of the son be doubled, it will exceed the father's age by 10 years Find the age of each

5. A person distributed £5 among 36 persons, old men and women, giving 3*s* to each man and 2*s* 6*d* to each woman How many were there of each?

6. There are two places 154 miles distant from each other, from which two persons A and B set out at the same instant with a design to meet on the road, A travelling at the rate of 3 miles in 2 hours and B at the rate of 5 miles in 4 hours How long and how far did each travel before they met?

7. A labourer was engaged for 36 days, upon the condition that he should receive 2*s* 6*d* for every day he worked, but should pay 1*s* 6*d* for every day he was idle. At the end of the time he received 58*s* How many days did he work?

8. A person bought a picture at a certain price and paid the same price for the frame. if the frame had cost £1 less and the picture 15*s* more, the price of the frame would have been only half that of the picture Find the cost of the picture
[C U Entr Paper, 1860]

9. A post has a fourth of its length in the mud, a third of its length in the water and 10 feet above the water, what is its length? [C U Entr Paper, 1863]

10. A labourer is engaged for 30 days on condition that he receives 2*s* 6*d* for each day he works, and loses 1*s* for each day he is idle he receives £2 7*s* in all How many days does he work, and how many days is he idle?

11. A can do a piece of work, in 9 days, B in twice that time, C can only do $\frac{1}{4}$ as much as A, in a day, how long would A, B and C, working together, require to do the same piece of work? [C U Entr Paper, 1876]

12. Two sums of money are together equal to £54 12*s* and there are as many pounds in the one as shillings in the other What are the sums ? [C U Entr Paper, 1885]

13. A certain sum is to be divided among *A*, *B* and *C* *A* is to have £30 less than the half, *B* is to have £10 less than the third part, and *C* is to have £8 more than the fourth part What does each receive ?

14. A farmer wishing to purchase a number of sheep, found that if they cost him £2 2*s* a head, he would not have money enough by £1 8*s* , but if they cost him £2 a head, he would then have £2 more than he required Find the number of sheep, and the money which he had ?

15. Two coaches start at the same time from York and London, a distance of 200 miles, travelling, one at $9\frac{1}{2}$ miles an hour, the other at $9\frac{1}{4}$ Where will they meet and in what time from starting ?

16. I bought a certain number of apples at three a penny, and five-sixths of that number at four a penny , by selling them at sixteen for six pence I gained $3\frac{1}{2}d$, how many apples did I buy ?

17. A number consists of two digits , the sum of the digits is 5, and if the left digit be increased by 1 it will be equal to $\frac{1}{8}$th of the number Find the number

18. A number consists of two digits, the digit in the ten's place exceeds that in the unit's place by 5, and if 5 times the sum of the digits be subtracted from the number, the digits will be inverted Find the number

19. There is a number, the sum of whose digits is 5, and if 10 times the digit in the place of tens be added to 4 times the digit in the place of units, the number will be inverted What is the number ?

20. Divide the number 39 into four parts, such that if the first be increased by 1, the second diminished by 2, the third multiplied by 3, and the fourth divided by 4, the results will all be equal

21. Divide 60 into 4 parts, such that if the first be diminished by 3, the second increased by 11, the third multiplied by 4, and the fourth divided by 2, the results will all be equal

22. Divide the number 116 into four such parts that if the first be increased by 5, the second diminished by 4, the third multiplied by 3, and the fourth divided by 2, the result in each case shall be the same

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CHAPTER XVIII

SIMPLE SIMULTANEOUS EQUATIONS AND PROBLEMS

1. Simple Simultaneous Equations.

116. Introductory remarks. The equation $x-y=2$, in which x and y are both unknown, evidently admits of an infinite number of solutions, for any pair of numbers, whose difference is 2 will satisfy it [For instance, the equation will be satisfied if $x=3$, $y=1$, if $x=4$, $y=2$, if $x=5$, $y=3$; if $x=6$ $y=4$, and so on] If however x and y be such that they must *also* satisfy the equation $x+y=8$, then of the different pairs of numbers whose difference is 2, we shall have to reject all excepting that of which the sum is 8 Thus the two equations

$$\left.\begin{aligned} x-y&=2 \\ x+y&=8 \end{aligned}\right\}$$

will *both* be satisfied by the *same* values of x and y, *only when* $x=5$ and $y=3$

Again it may be seen that the three equations,

$$\left.\begin{aligned} x+y+z&=6 \\ x-y+z&=4 \\ x+y-z&=2 \end{aligned}\right\}$$

will be satisfied by the *same* values of x, y z, *only when* $x=3$, $y=1$, $z=2$ The equations may be *individually* satisfied by innumerable sets of values of the unknown quantities, but there is *only one* set which will satisfy them *all*

Two or more equations (like those just referred to) which are *all* satisfied by the same values of the unknown quantities involved in them are called **simultaneous equations.** They are said to be **simple** or of the first degree when each unknown quantity occurs only in the first power, and the product of the unknown quantities does not occur

We shall consider first of all simultaneous equations involving two unknown quantities and later on, those that

involve more than two There are three general methods for solving such equations and we shall treat them successively in the next three articles

117. First Method : From either equation find one of the unknown quantities in terms of the other and substitute the value thus found in the other equation

Example 1. Solve $\left.\begin{aligned} 5x-24y&=16 \\ 4x-y&=31 \end{aligned}\right\}$

From the second equation, we have

$$y=4x-31 \tag{1}$$

Substituting this value of y in the 1st equation, we have

$$5x-24(4x-31)=16$$

or, $$5x-96x+744=16,$$

$$-91x=-728, \qquad x=8$$

Hence, from (1), $y=4\times8-31=1$

Thus, we have $x=8$ and $y=1$

Note *The student is recommended to verify for his own satisfaction that these values of x and y do really satisfy **both** of the given equations*

Example 2. Solve $\dfrac{3x-5y}{2}+3=\dfrac{2x+y}{5}$; $8-\dfrac{x-2y}{4}=\dfrac{x}{2}+\dfrac{y}{3}$.

Multiplying both sides of the first equation by 10,

we have $5(3x-5y)+30=2(2x+y)$,

or, $15x-25y+30=4x+2y$,

$$11x=27y-30 \tag{1}$$

Multiplying both sides of the second equation by 12,

we have $96-3(x-2y)=6x+4y$,

or, $96-3x+6y=6x+4y$,

$$2y-9x+96=0 \tag{2}$$

From (1), we have $$x=\frac{27y-30}{11}. \tag{3}$$

Substituting this value of x in (2), we have

$$2y-\frac{9(27y-30)}{11}+96=0$$

$$22y-9(27y-30)+1056=0$$

or, $$22y-243y+270+1056=0$$

$$221y=1326 \qquad y=6$$

Hence, from (3) $x=\dfrac{27\times6-30}{11}=\dfrac{132}{11}=12$

Thus we have $x=12$ and $y=6$

EXERCISE 63.

Solve the following equations

1. $\left.\begin{array}{l} x+4y=14 \\ 7x-3y=5 \end{array}\right\}$

2. $\left.\begin{array}{l} 5x-8y=9 \\ 13x+7y=79 \end{array}\right\}$

3. $\left.\begin{array}{l} 2x+3y=32 \\ 11y-9x=3 \end{array}\right\}$

4. $\left.\begin{array}{l} 9x-4y=8 \\ 13x+7y=101 \end{array}\right\}$

5. $\left.\begin{array}{l} x+ay=b \\ ax-by=c \end{array}\right\}$

6. $\left.\begin{array}{l} 2x-\frac{1}{5}(y-3)=4 \\ 3y+\frac{1}{3}(x-2)=9 \end{array}\right\}$

7. $\left.\begin{array}{l} \frac{1}{2}(x+y)=\frac{1}{3}(2x+4) \\ \frac{1}{4}(x-y)=\frac{1}{2}(x-24) \end{array}\right\}$

8. $\left.\begin{array}{l} \frac{1}{3}(x-y)=\frac{1}{4}(y-1) \\ \frac{1}{7}(4x-5y)=x-7 \end{array}\right\}$

[C U Entr Paper, 1872]

9. $\left.\begin{array}{l} \frac{1}{2}(3x-2y)-3=\frac{1}{4}(2x-y) \\ \frac{1}{2}(5x-4y)-3=\frac{1}{3}(4x-3y) \end{array}\right\}$

10. $\left.\begin{array}{l} \frac{1}{6}(2x+3y)+\frac{1}{3}x=8 \\ \frac{1}{2}(7y-3x)-y=11 \end{array}\right\}$

118. Second Method: From each equation find the value of the same unknown quantity in terms of the other and equate the values thus found

Example 1. Solve $\left.\begin{array}{l} 6x-5y=11 \\ 2x+3y=27 \end{array}\right\}$

From the 1st equation, we have

$$5y=6x-11$$

$$y=\frac{6x-11}{5}. \qquad (1)$$

From the 2nd equation we have

$$3y=27-2x$$

$$y=\frac{27-2x}{3}. \qquad (2)$$

Hence from (1) and (2), we have

$$\frac{6x-11}{5}=\frac{27-2x}{3},$$

$$3(6x-11)=5(27-2x),$$

or, $$18x-33=135-10x,$$

$$\therefore \quad 28x=168, \qquad x=6$$

Hence from (1) $y=\frac{6\times 6-11}{5}=5$

Thus, we have $x=6$ and $y=5$

Example 2. Solve $\left.\begin{array}{l}\frac{7+x}{5}-\frac{2x-y}{4}=3y-5\\ \frac{5y-7}{2}+\frac{4x-3}{6}=18-5x\end{array}\right\}$

[Calcutta University Entrance Paper, 1880]

Multiplying both sides of the 1st equation by 20,

we have $4(7+x)-5(2x-y)=20(3y-5)$,

or, $$28-6x+5y=60y-100,$$

$$55y+6x=128 \qquad (1)$$

Multiplying both sides of the 2nd equation by 6,

we have $3(5y-7)+(4x-3)=6(18-5x)$,

or, $$15y+4x-24=108-30x,$$

$$15y+34x=132 \qquad (2)$$

From (1), $y=\frac{128-6x}{55}$ (3)

From (2), $y=\frac{132-34x}{15}$. (4)

Hence, from (3) and (4), we have

$$\frac{128-6x}{55}=\frac{132-34x}{15}; \qquad \text{or,} \qquad \frac{64-3x}{11}=\frac{66-17x}{3},$$

[multiplying both sides by $\frac{5}{2}$]

$$3(64-3x)=11(66-17x),$$

or $$192-9x=726-187x,$$

$$178x=534, \qquad x=3$$

Hence, from (3) $y=\frac{128-18}{55}=\frac{110}{55}=2$

Thus, we have $x=3$ and $y=2$

EXERCISE 64.

Solve the following equations

1. $\left.\begin{aligned}5x-3y&=9\\5y+2x&=16\end{aligned}\right\}$ **2.** $\left.\begin{aligned}3y-4x&=1\\3x+4y&=18\end{aligned}\right\}$

3. $\left.\begin{aligned}3x-7y&=7\\11x+5y&=87\end{aligned}\right\}$ **4.** $\left.\begin{aligned}y(3+x)&=x(7+y)\\4x+9&=5y-14\end{aligned}\right\}$

5. $\left.\begin{aligned}32x-25y&=28\\14x+15y&=116\end{aligned}\right\}$ **6.** $\left.\begin{aligned}\tfrac{1}{7}(3x+y)&=\tfrac{1}{6}(2x+y+1)\\8-\tfrac{1}{6}(x-y)&=6\end{aligned}\right\}$

7. $\left.\begin{aligned}\tfrac{11}{13}(5x-6y)+3x&=4y-2\\\tfrac{1}{5}(5x+6y)-\tfrac{1}{4}(3x-2y)&=2y-2\end{aligned}\right\}$

8. $\left.\begin{aligned}2x-\tfrac{1}{4}(y+3)&=7+\tfrac{1}{5}(3y-2x)\\4y+\tfrac{1}{3}(x-2)&=26\tfrac{1}{2}-\tfrac{1}{2}(2y+1)\end{aligned}\right\}$

9. $\left.\begin{aligned}2x-\tfrac{1}{3}(2y-1)&=3\tfrac{5}{24}+\tfrac{1}{4}(3x-2y)\\4y-\tfrac{1}{4}(5-2x)&=6-\tfrac{1}{6}(3-2y)\end{aligned}\right\}$ [C U 1873.]

10. $\frac{x}{3}-\frac{2}{y}=1,\ \frac{x}{4}+\frac{3}{y}=3$ [A U 1923.]

119. Third Method: "Multiply the equations by such numbers as will make the co-efficient of one of the unknown quantities the same in the two resulting equations, then by addition or subtraction we can form an equation containing only the other unknown quantity."

Example 1. Solve $\left.\begin{aligned}3x-4y&=5\\5x+2y&=17\end{aligned}\right\}$

Multiplying the 2nd equation by 2, we have

$$\left.\begin{aligned}10x+4y&=34\\3x-4y&=5\end{aligned}\right\}$$
and the first equation is

Hence, by addition, $13x=39$, $\therefore x=3$

Substituting this value of x in the 1st equation,

we have $4y=9-5=4$, $\therefore y=1$

Thus, we have $x=3,\ y=1$

Example 2. Solve $\left.\begin{aligned}5x+9y&=89\\2x-17y&=15\end{aligned}\right\}$

Multiplying the 1st equation by 2, and the 2nd by 5,

we have $10x+18y=178$
and $10x-85y=75$

Hence, by subtraction, we have

$$103y = 103, \qquad \therefore\ y = 1$$

Substituting this value of y in the 2nd equation,

we have $\quad 2x = 15 + 17 = 32, \qquad \therefore\ x = 16$

Thus, we have $x = 16, \quad y = 1$

Note *We might as well have multiplied the 1st equation by 17 and the 2nd equation by 9 and added the two resulting equations, this would have given us the value of x But we have preferred the other alternative because, the co-efficients of x being smaller, the required multiplications have been more easily effected*

Example 3. Solve $\left.\begin{aligned} 23x - 24y &= 21 \\ 25x - 16y &= 43 \end{aligned}\right\}$

Multiplying the 1st equation by 2, and the 2nd by 3,

we have $\qquad \left.\begin{aligned} 46x - 48y &= 42 \\ \text{and} \quad 75x - 48y &= 129 \end{aligned}\right\}$

Hence, by subtraction, we have

$$29x = 87, \qquad \therefore\ x = 3$$

Substituting this value of x in the 2nd equation,

we have $\quad 16y = 75 - 43 = 32, \qquad \therefore\ y = 2$

Thus, we have $x = 3 \quad y = 2$

Note *It may be noticed that the co-efficient of y in each of the resulting equations is the* **least common multiple** *of 24 and 16 and this is all that is required The process would have been unnecessarily tedious if the 1st equation were multiplied by 16 and the 2nd by 24*

Example 4. Solve $\left.\begin{aligned} \frac{x-2}{2} - \frac{x+y}{14} &= \frac{x-y-1}{8} - \frac{y+12}{4} \\ \frac{x+7}{3} + \frac{y-5}{10} &= 1 - x - \frac{5(y+1)}{7} \end{aligned}\right\}$

[C U Entrance Paper, 1882]

From the 1st equation, we have

$$\frac{7(x-2) - (x+y)}{14} = \frac{(x-y-1) - 2(y+12)}{8}$$

or, $$\frac{6x - y - 14}{7} = \frac{x - 3y - 25}{4},$$

or, $24x-4y-56=7x-21y-175,$

or, $17x+17y=-119,$

or, $x+y=-7$. (1)

From the 2nd equation, we have

$$\frac{10(x+7)+3(y-5)}{30}=\frac{7(1-x)-5(y+1)}{7}$$

or $$\frac{10x+3y+55}{30}=\frac{2-7x-5y}{7}$$

or, $70x+21y+385=60-210x-150y,$

or, $280x+171y=-325$ (2)

Multiplying (1) by 171, we have

$$\left.\begin{aligned} 171x+171y&=-1197 \\ \text{also}\quad 280x+171y&=-\ 325 \end{aligned}\right\}$$

Hence, by subtraction,

$$109x=872, \qquad x=8$$

Substituting this value of x in (1),

we have $y=-7-8=-15$

Thus, we have $x=8,\ y=-15$

Example 5. Solve $$\left.\begin{aligned} \frac{2}{x}+\frac{3}{y}&=1 \\ \frac{7}{x}+\frac{4}{y}&=1\tfrac{7}{8} \end{aligned}\right\}$$

Multiplying the 1st equation by 4, and the 2nd by 3, we have

$$\frac{8}{x}+\frac{12}{y}=4 \text{ and } \frac{21}{x}+\frac{12}{y}=\frac{45}{8}.$$

Hence by subtraction,

$$\frac{13}{x}=\frac{13}{8}, \qquad x=8$$

Substituting this value of x in the 1st equation,

we have $$\frac{3}{y}=1-\frac{1}{4}=\frac{3}{4}, \qquad y=4$$

Thus, we have $x=8,\ y=4$

EXERCISE 65.

Solve the following equations

1. $\left.\begin{aligned} 7x - 5y &= 11 \\ 3x + 2y &= 13 \end{aligned}\right\}$

2. $\left.\begin{aligned} 13x + 6y &= 58 \\ 5x - 11y &= 9 \end{aligned}\right\}$

3. $\left.\begin{aligned} 8x - 9y &= 20 \\ 7x - 10y &= 9 \end{aligned}\right\}$

4. $\left.\begin{aligned} 25x - 14y &= 8 \\ 12x + 7y &= 45 \end{aligned}\right\}$

5. $\left.\begin{aligned} 12x + 11y &= 70 \\ 8x - 7y &= 18 \end{aligned}\right\}$

6. $\left.\begin{aligned} 13x - 14y &= 22 \\ 17x - 21y &= 18 \end{aligned}\right\}$

7. $\left.\begin{aligned} 28x - 15y &= 41 \\ 21x + 13y &= 55 \end{aligned}\right\}$

8. $\left.\begin{aligned} 19x + 24y &= 34 \\ 23x + 36y &= 62 \end{aligned}\right\}$

9. $\left.\begin{aligned} 47x - 56y &= 123 \\ 25x + 84y &= 293 \end{aligned}\right\}$

10. $\left.\begin{aligned} 51x - 16y &= 3 \\ 68x + 23y &= 137 \end{aligned}\right\}$

11. $\left.\begin{aligned} 52x - 9y &= 34 \\ 39x + 14y &= 67 \end{aligned}\right\}$

12. $\left.\begin{aligned} 12x + 85y &= -49 \\ 19x - 34y &= 91 \end{aligned}\right\}$

13. $\left.\begin{aligned} 65x - 14y &= 9 \\ 91x - 15y &= 31 \end{aligned}\right\}$

14. $\left.\begin{aligned} 15x + 46y &= 17 \\ 13x + 69y &= 73 \end{aligned}\right\}$

15. $\left.\begin{aligned} 14x + 81y &= 53 \\ 17x + 135y &= 101 \end{aligned}\right\}$

16. $\left.\begin{aligned} 5x + 11y &= 146 \\ 11x + 5y &= 110 \end{aligned}\right\}$

17. $\left.\begin{aligned} ax + by &= c \\ a^2x + b^2y &= c^2 \end{aligned}\right\}$

[C U Entr Paper 1881]

18. $\left.\begin{aligned} \frac{x+y}{2} + \frac{3x-5y}{4} &= 2 \\ \frac{x}{14} + \frac{y}{18} &= 1 \end{aligned}\right\}$

[C U Entr Paper, 1876]

19. $\left.\begin{aligned} \frac{4x+5y}{40} &= x - y \\ \frac{2x-y}{3} + 2y &= \frac{1}{2} \end{aligned}\right\}$

20. $\left.\begin{aligned} \frac{4x-3y-7}{5} &= \frac{3x}{10} - \frac{2y}{15} - \frac{5}{6} \\ \frac{y-1}{3} + \frac{x}{2} - \frac{3y}{20} &= \frac{y-x}{15} + \frac{x}{6} + \frac{11}{10} \end{aligned}\right\}$

21. $\left.\begin{aligned} \frac{5x-3y}{12} + \frac{7x-5y}{15} &= 1 - \frac{25x+3y}{60} \\ \frac{(3\frac{1}{2})x+2y-5}{16} + \frac{11x-(4\frac{1}{3})y+17}{11} &= \frac{19}{22} + \frac{17x-10y+2}{3} \end{aligned}\right\}$

22. $\left.\begin{aligned} \frac{3x-5y}{3} - \frac{2x-8y-33}{12} &= \frac{y}{2} + \frac{x}{3} + \frac{1}{4} \\ 3\tfrac{1}{2}\left(\frac{x}{7} + \frac{y}{4} + 1\tfrac{1}{3}\right) &= 3\tfrac{1}{3}\left(4x - \frac{y}{8} - 24\right) \end{aligned}\right\}$

23. $\left.\begin{array}{l} 2\,4x+\,32y-\dfrac{18x-\,025}{25}=\,8x+\dfrac{5\,2+\,01y}{5} \\ \dfrac{2y+5}{1\,5}=\dfrac{49x-7}{4\,2} \end{array}\right\}$

24. $\left.\begin{array}{l} \dfrac{4}{x}+\dfrac{10}{y}=2 \\ \dfrac{3}{x}+\dfrac{2}{y}=\dfrac{19}{20} \end{array}\right\}$ [C U Entrance Paper, 1879]

25. $\left.\begin{array}{l} \dfrac{2}{x}+\dfrac{3}{y}=2 \\ \dfrac{5}{x}+\dfrac{10}{y}=5\frac{1}{6} \end{array}\right\}$ [C U Entr Paper 1887]

26. $\left.\begin{array}{l} \dfrac{a}{x}+\dfrac{b}{y}=m \\ \dfrac{b}{x}+\dfrac{a}{y}=n \end{array}\right\}$

27. $\left.\begin{array}{l} \dfrac{1}{3x}+\dfrac{1}{5y}=1 \\ \dfrac{1}{5x}+\dfrac{1}{3y}=1\frac{2}{15} \end{array}\right\}$

28. $\left.\begin{array}{l} \dfrac{3}{y}-\dfrac{1}{x}=1 \\ \dfrac{2}{5x}+\dfrac{5}{2y}=7 \end{array}\right\}$

29. $\left.\begin{array}{l} \dfrac{x}{4}+\dfrac{2}{y}=2 \\ \dfrac{2x}{5}+\dfrac{3}{2y}=2\frac{[illegible]}{20} \end{array}\right\}$

30. $\left.\begin{array}{l} \dfrac{1}{5x}+\dfrac{y}{9}=5 \\ \dfrac{1}{3x}+\dfrac{y}{2}=14 \end{array}\right\}$

[C U Entr Paper, 1870]

II. Problems leading to simple equations with more than one unknown quantity.

Easy Problems.

120. Example 1. *A* and *B* each had a number of mangoes *A* said to *B*, 'If you give me 30 of your mangoes, my number will be *twice* yours ' *B* replied, "If you give me 10, my number will be *thrice* yours" How many had each?

Let x= the number of mangoes *A* had,

and y= ,, ,, ,, *B* ,,

Then in accordance with what *A* said, we must have the equation $$x+30=2(y-30), \tag{1}$$

and in accordance with *B*'s reply, we must have the equation
$$y+10=3(x-10), \tag{2}$$

From (2) $3x-y=40$ or $6x-2y=80$ (3)

and from (1) $x-2y=-90$ (4)

Hence, by subtraction, $5x = 170$, $\quad x = 34$

Substituting this value of x in (4) we have

$$2y = 34 + 90 = 124, \qquad y = 62$$

Thus A had 34 mangoes and B had 62

Example 2. A certain fraction becomes 2 when 7 is added to its numerator, and 1 when 2 is subtracted from the denominator What is the fraction?

Let $\dfrac{x}{y}$ represent the fraction

Then we have $\dfrac{x+7}{y} = 2$ (1)

and $\dfrac{x}{y-2} = 1$ (2)

From (1) $x + 7 = 2y$ $\qquad x = 2y - 7$

From (2), $\qquad x = y - 2$

Therefore, $2y - 7 = y - 2$, whence $y = 5$

Hence $\quad x = 5 - 2 = 3$

Thus the fraction is $\frac{3}{5}$

Example 3. Two men and 7 boys can do in 4 days a piece of work which would be done in 3 days by 4 men and 4 boys How long would it take one man or one boy to do it?

Let x = the number of days in which one man would do the work,

and y = the number of days in which one boy would do it

Then in one day a man does $\dfrac{1}{x}$th of the work and a boy does $\dfrac{1}{y}$th of it

Hence, since 2 men and 7 boys do $\frac{1}{4}$th of the work in one day we must have

$$\frac{2}{x} + \frac{7}{y} = \frac{1}{4}. \tag{1}$$

Again since 4 men and 4 boys do $\frac{1}{3}$rd of the work in one day we must have

$$\frac{4}{x} + \frac{4}{y} = \frac{1}{3}. \tag{2}$$

Multiplying (1) by 2, and subtracting (2) from the resulting equation, we have

$$\frac{10}{y}=\frac{1}{2}-\frac{1}{3}=\frac{1}{6}; \qquad y=60$$

Hence, from (2), $\frac{4}{x}=\frac{1}{3}-\frac{1}{15}=\frac{4}{15}$; $\qquad x=15$

Thus one man would do the work in 15 days and one boy in 60 days

Example 4. Two plugs are opened in the bottom of a cistern containing 192 gallons of water, after 3 hours one of them becomes stopped, and the cistern is emptied by the other in 11 hours, had 6 hours elapsed before the stoppage, it would have only required 6 hours more to empty it How many gallons will each plug-hole discharge in one hour, supposing the discharge to be uniform?

Let x, y be the numbers of gallons of water which the plugs can respectively discharge in an hour

In the first case, the first plug remains opened for 3 hours, and the second for 3+11 or 14 hours

Hence, $\qquad 3x+14y=192 \qquad (1)$

In the second case, the first plug remains opened for 6 hours and the second for 6+6 or 12 hours

Hence $\qquad 6x+12y=192 \qquad (2)$

Multiplying (1) by 2 and subtracting (2) from the resulting equation, we have

$$16y=2\times192-192$$
$$=192, \qquad y=12$$

Hence, from (2), $6x=192-144=48$, $\qquad x=8$

Thus the plug-holes respectively discharge 8 and 12 gallons in an hour

Example 5. The dimensions of a rectangular court are such that if the length were increased by 3 yards, and the breadth diminished by the same, its area would be diminished by 18 square yards, and if its length were increased by 3 yards, and its breadth increased by the same, its area would be increased by 60 square yards, find the dimensions

[Calcutta University Entrance Paper, 1888]

Let x yards = length of the court,

and y yards = its breadth

Then from the first condition of the problem, we have

$$(x+3)(y-3)=xy-18 \tag{1}$$

and from the second condition,

$$(x+3)(y+3)=xy+60 \tag{2}$$

From (1), $\quad 3y-3x=-9, \quad$ (3)

or $\quad y-x=-3 \quad$ (4)

From (2), $\quad 3y+3x=51,$

or, $\quad y+x=17 \quad$ (4)

From (3) and (4), by addition,

$$2y=14, \qquad y=7,$$

and by subtraction, $\quad 2x=20, \qquad x=10$

Thus the length of the court is 10 yards, and the breadth is 7 yards

Example 6. There is a certain number, to the sum of whose digits if you add 7, the result will be three times the left-hand digit, and if from the number itself you subtract 18, the digits will be inverted Find the number

Let x and y be the left and right-hand digits respectively: then the required number is represented by $10x+y$, and the number with inverted digits $=10y+x$

Hence, by the conditions of the problem.

$$x+y+7=3x \tag{1}$$

and $\quad (10x+y)-18=10y+x \quad$ (2)

From (1) $\quad 2x-y=7 \quad$ (3)

and from (2), $9x-9y=18, \quad$ or, $x-y=2 \quad$ (4)

Subtracting (4) from (3), we have

$$x=7-2=5$$

Hence, from (4), $\quad y=5-2=3$

Thus the required number is 53

Example 7. A and B play at bowls, and A bets B three shillings to two upon every game, after a certain number of games it appears that A has won three shillings; but if A had bet five shillings to two and lost one game more out of the same number, he would have lost thirty shillings How many games did each win ?

Let x = number of games that A won,
and y = " " " " B "

Then the total number of games played is evidently $x+y$

Now, since A receives from B, 2s for every game that he wins and gives B, 3s for every game that he loses (i e, for every game that B wins), his total gain must be equal to $(2x-3y)$ sillings

Hence, $$2x-3y=3 \qquad (1)$$

According to the other condition, A would have gained $2(x-1)$ shillings, and lost $5(y+1)$ shillings, and therefore his total loss would have been $[5(y+1)-2(x-1)]$ shillings

Hence, $$5(y+1)-2(x-1)=30,$$
or, $$5y-2x=23 \qquad (2)$$

From (1) and (2), by addition,
$$2y=26, \qquad y=13$$

Hence, from (1), $x=\frac{3+39}{2}=21$

Thus, A won 21 games and B won 13 games

EXERCISE 66.

1. What fraction is that whose numerator being doubled and denominator increased by 7, the value becomes $\frac{2}{3}$, but the denominator being doubled, and the numerator increased by 2, the value becomes $\frac{3}{5}$?

2. Find two numbers such that if the first be added to 5 times the second, the sum is 52, and if the second be added to 8 times the first, the sum is 65

3. Find two numbers such that five times the greater exceeds four times the less by 22, and three times the greater together with seven times the less is 32

4. What numbers are those whose difference is 45, and the quotient of the greater by the less is 4?

5. There are two numbers such that one-fourth of the greater added to one-third of the less is 11, and if one-fifth of the less be taken from one-eighth of the greater, the remainder is nothing, find the numbers

6. A certain fraction becomes $\frac{1}{2}$ when 1 is subtracted from its denominator, and 1 when 7 is added to its numerator. What is the fraction?

7. What fraction is that which, if 1 be added to the numerator, becomes 1, and if 1 be added to the denominator, becomes $\frac{1}{2}$? [Calcutta University Entrance Paper, 1862]

8. A certain fraction becomes $\frac{1}{2}$ when its numerator is increased by unity, and $\frac{1}{3}$ when its denominator is increased by unity. What is the fraction?

9. *A* and *B* have 39 rupees between them, but if *A* were to lose two-thirds of his money, and *B* three-fourths of his, they would then have only 11 rupees. How much has each?

10. Two numbers are such that if 7 be added to the less, the sum is twice the greater, and if 4 be added to the greater, the sum is 3 times the less. Find the numbers.

11. Two persons, 27 miles apart, setting out at the same time, meet together in 9 hours if they walk in the same direction, but in 3 hours if they walk in opposite directions; find their rates of walking.

12. A banker was asked to pay £10 in sovereigns and half-crowns, so that the number of the latter should be exactly twice that of the former. How must he do it?

13. A man and a boy can do in 15 days a piece of work which would be done in 2 days by 7 men and 9 boys. How long would it take one man to do it?

14. A rectangle is of the same area as another which is 6 yards longer and 4 yards narrower; it is also of the same area as a third, which is 8 yards longer and 5 yards narrower. What is its area?

15. If 15 lbs. of tea and 17 lbs. of coffee together cost £3. 5*s*. 6*d*., and 25 lbs. of tea and 13 lbs. of coffee together cost £4. 6*s*. 2*d*., find the price of each per pound.

16. *A* takes 3 hours longer than *B* to walk 30 miles; but if he doubles his pace he takes 2 hours less time than *B*; find their rates of walking.

17. Says Charles to William, "If you give me 10 of your marbles, I shall then have just *twice* as many as you"; but says William to Charles, "If you give me 10 of yours, I shall then have *three times* as many as you." How many had each?

18. Rs. 1100 are so divided among *A*, *B* and *C*, that if *A* were to give *B* Rs. 200, *B* would then have twice as much as *A*, and three times as much as *C*. How many rupees did *A*, *B* and *C* each receive originally? [C. U. Entr. Paper, 1872]

19. If a certain number be divided by the sum of its two digits the quotient is 6 and the remainder is 3 If the digits be inverted and the resulting number be divided by the sum of the digits, the quotient is 4 and the remainder 9 Find the number

20. Find that number of 2 figures, to which, if the number formed by changing the places of the digits, be added, the sum is 121 ; and if the smaller number be subtracted from the larger, the remainder is 9

21. A bill of 25 guineas was paid with crowns and half-guineas, and twice the number of half-guineas exceeded 3 times that of the crowns by 17 , how many were there of each?

22. A person sells to one person 9 horses and 7 cows for £300 , and to another, at the same prices, 6 horses and 13 cows for the same sum , what was the price of each ?

23. A and B received £5 17*s* for their wages, A having been employed for 15 and B for 14 days , and A received, for working four days, 11*s* more than B did for three days, what were their daily wages ?

24. A and B can do a piece of work in 16 days ; they work together for four days, when A leaves, and B finishes it in 36 days more , in what time would each do the work separately ?

25. If the numerator of a fraction is increased by 2 and the denominator by 1, it becomes equal to $\frac{5}{8}$, and if the numerator and denominator are each diminished by 1, it becomes equal to $\frac{1}{2}$, find the fraction

26. A traveller walks a certain distance , had he gone half a mile an hour faster, he would have walked it in four-fifths of the time , had he gone half a mile an hour slower, he would have been $2\frac{1}{2}$ hours longer on the road Find the distance

27. A certain number between 10 and 100 is eight times the sum of its digits, and if 45 be subtracted from it, the digits will be reversed , find the number

28. A and B lay a wager of 10*s* If A loses, he will have twenty-five shillings less than twice as much as B will then have , but if B loses, he will have five-seventeenths of what A will then have , find how much money each of them has

29. A farmer wishing to purchase a number of sheep found that if they cost him £2 2*s* a head, he would not have money enough by £1 8*s* , but if they cost him £2 a head, he

would then have £2 more than he required, find the number of sheep, and the money which he had

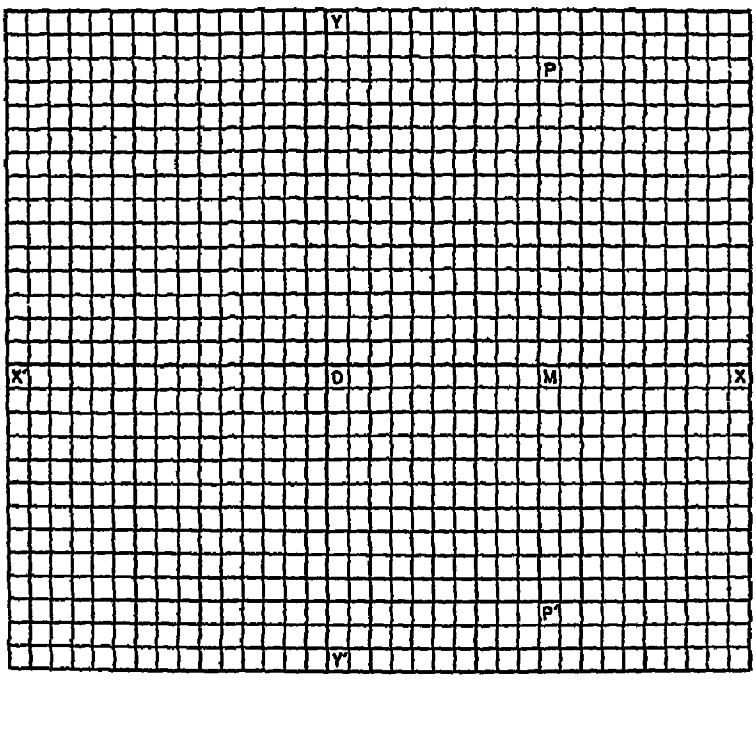
30. There is a number consisting of two digits, the number is equal to three times the sum of its digits, and if it be multiplied by three, the result will be equal to the square of the sum of its digits Find the number

CHAPTER XIX

GRAPHS OF SIMPLE EQUATIONS

121. In Chapter VII, we have discussed representations of numbers by geometric points We now propose to show how simple equations are represented graphically The following examples will make the subject clear

Example 1. If a point moves in such a manner that its abscissa is always equal to 5 units of length, find the path along which the point will move



Let twice the side of a small square represent the unit of length

On OX take the point M such that $OM=5$ units of length through M draw the straight line PMP' parallel to YOY'.

Now if any point be taken on the straight line PMP' its x will evidently be equal to 5 units of length, but this will *not* be so if the point be taken on either side of the line PMP'.

Hence the moving point will always be on the line PMP'

We see therefore that if a point moves in such a manner that its x is always equal to 5 units of length, the path along which the point will move is the straight line PMP' This fact is briefly expressed by saying that **the straight line PMP′ is the graph of the equation $x=5$.**

Note 1 *From the above it is clear that the graph of the equation $y=5$ is a straight line parallel to XOX'*

Note 2 *Generally speaking, the graph of the equation $x=a$ is a straight line parallel to the axis of y, and passing through a point on the axis of x which is at a distance of a units of length from the origin, and the graph of the equation $y=b$ is a straight line parallel to the axis of x, and passing through a point on the axis of y, which is at a distance of b units of length from the origin*

Note 3 *Evidently therefore the graph of the equation $x=0$ is the axis of y itself, and the graph of the equation $y=0$ is the axis of x itself*

Example 2. If a point moves in such a manner that its x and y are always connected by the relation $y=3x$, find the path along which the point will move.

Since $y=3x$ $\left.\begin{array}{l}\text{when } x=0\\ \text{we have, } y=0\end{array}\right\}$, and $\left.\begin{array}{l}\text{when } x=3\\ \text{we have, } y=9\end{array}\right\}$.

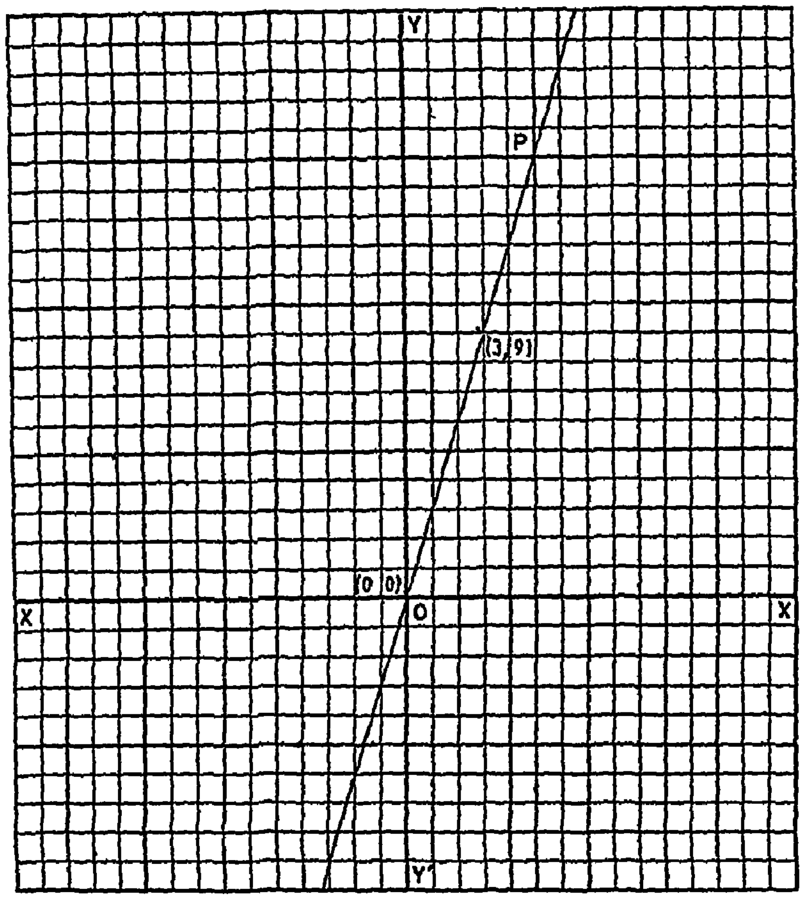
Evidently therefore (0 0) and (3 9) are two positions of the moving point

Take the length of a small square as the unit of length (The figure is on the next page)

Join the points (0 0) and (3 9) and produce the straight line both ways Then this straight line will be the required path

Take any point P on this straight line The co-ordinates of P are found to be 5 and 15, which evidently satisfy the given relation Similarly, the co-ordinates of any other point on this straight line may be shown to satisfy the given

relation But the co-ordinates of a point which is outside the line OP will *not* satisfy the given relation, as can be easily verified



Hence, the moving point will always be on the line OP and never stray out of it

Thus it is found that if a point moves in such a way that its x and y are invariably connected by the relation $y=3x$, the path along which the point will move is the straight line OP In other words, **the line OP is the graph of the equation $y=3x$.**

Note. *Generally speaking, the graph of the equation $y=mx$, where m is any given number, is a straight line passing through the origin*

Example 3. If a point moves in such a way that its x and y are invariably connected by the relation $y=-4x+5$, find the path along which the point will move

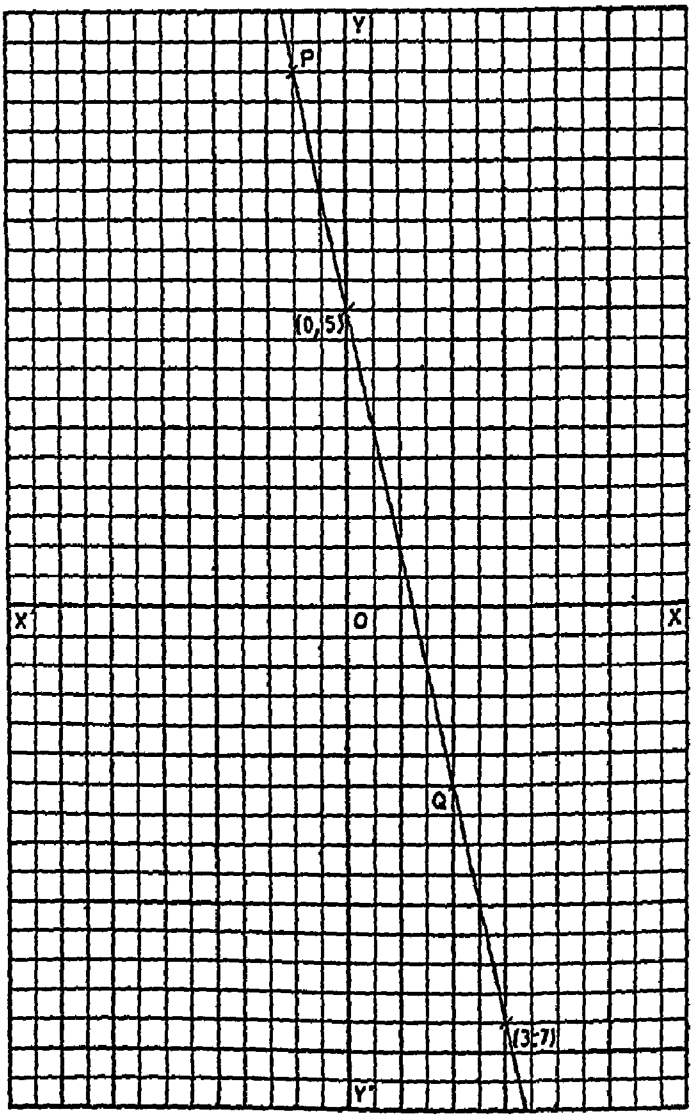
From the given relation,

$$\text{since, when } \left.\begin{array}{l} x=0 \\ y=5 \end{array}\right\}, \qquad \text{and when } \left.\begin{array}{l} x=3 \\ y=-7 \end{array}\right\}.$$

(the second line of each pair reading "we have,")

Evidently therefore (0, 5) and (3, −7) are two positions of the moving point

Let twice the side of a small square represent the unit of length Join the points (0, 5) and (3, −7), andproduce the straight line both ways Then this straight line will be the required path



Take a point P on this straight line. The co-ordinates of P, which are found to be −1 and 9, satisfy the given relation.

Take another point Q on the straight line; its co-ordinates which are found to be 2 and -3, also satisfy the given relation Similarly the co-ordinates of any other point on this straight line may be shown to satisfy the given relation But if a point be taken outside the line PQ, its co-ordinates will *not* satisfy the given relation, as can be easily seen Hence the moving point will always be on the line PQ and never stray out of it

Thus it is found that if a point moves in such a manner that its co-ordinates always satisfy the equation $y = -4x+5$ the path along which the point will move is the str line PQ In other words, **the str. line PQ is the graph of the equation $y = -4x+5$.**

Note 1 *Generally speaking, the graph of the equation $y = mx+c$, where m and c are any given numbers, is a straight line passing through the point (o, c)*

Note 2. *As every equation of the first degree in x and y can be reduced to the form $y = mx+c$, it is clear that* ***graphs of all simple equations are straight lines.***

Note 3. *The graph of the equation $y = mx+c$ is also said to be* ***the graph of the expression $mx+c$.***

Note 4. *The graph of any given equation may be defined to be the path described by a point which moves in such a manner that in every position of the point its co-ordinates satisfy the given equation*

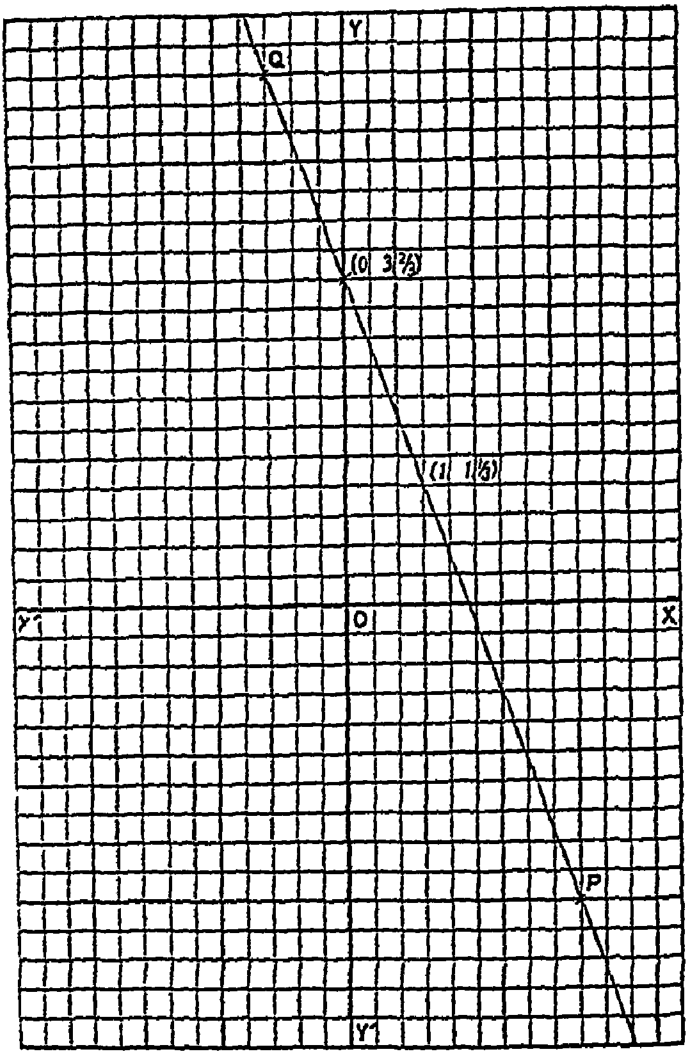
Example 4. Draw the graph of the equation $7x+3y=11$

When $\left.\begin{matrix} x=0 \\ y=3\frac{2}{3} \end{matrix}\right\}$, and when $\left.\begin{matrix} x=1 \\ y=1\frac{1}{3} \end{matrix}\right\}$

Evidently therefore $(0, 3\frac{2}{3})$ and $(1, 1\frac{1}{3})$ are two points on the graph

Let 3 times the side of a small square represent the unit of length Join the points $(0, 3\frac{2}{3})$ and $(1, 1\frac{1}{3})$, and produce the straight line both ways Then this straight line will be the required graph (See diagram on page 230)

Take any point P on the line; its co-ordinates, which are found to be 3 and $-3\frac{1}{3}$ satisfy the given relation Take any other point Q on the line, its co-ordinates which are found to be -1 and 6, also satisfy the given relation Similarly it may be shown that the co-ordinates of any point that may be taken on the line PQ will satisfy the given relation, but the co-ordinates of any point which is outside PQ will *not* Hence the line PQ is the required graph



Note 1. *The graph of the equation $7x+3y=11$ is also said to be the graph of the expression* $\frac{11-7x}{3}$.

Note 2. *The straight line PQ being the graph of the equation $7x+3y=11$, this equation is said to be the equation of the straight line PQ.*

Note 3 *The equation of a given straight line means the equation which is satisfied by the co-ordinates of every point on that straight line.*

Example 5. Find the equation of the straight line which passes through the points (1, 1) and (3 $-\frac{1}{2}$)

Let $y=mx+c$ be the required equation

This equation being satisfied by (1, 1) and also by $(3, -\frac{1}{2})$, we must have

$$\left.\begin{aligned} 1 &= m+c \\ \text{and } -\tfrac{1}{2} &= 3m+c \end{aligned}\right\} \qquad \text{Hence, } 2m = -\tfrac{3}{2}, \text{ and } \therefore m = -\tfrac{3}{4}, \text{ whence } c = 1+\tfrac{3}{4} = \tfrac{7}{4}$$

Thus, the required equation is $y = -\frac{3}{4}x + \frac{7}{4}$,

or, $3x+4y=7$

EXERCISE 67.

1. Draw the graphs of the following equations

(1) $x = 8$ (2) $x = 13$ (3) $x+11=0$

(4) $y=-7$ (5) $y-9=0$ (6) $y+10=0$

2. Draw the graphs of the following equations

(1) $y=x$ (2) $y=-x$ (3) $y=2x$

(4) $y+2x=0$ (5) $y=-3x$ (6) $3y=5x$

(7) $7y+8x=0$ (8) $6y+13x=0$

3. Draw the graphs of the following equations

(1) $y=3x+4$ (2) $y=7x-8$ (3) $y=-5x+9$

(4) $y=-8x-11$ (5) $3y=7x+4$ (6) $-6y=7x-10$

4. Draw the graphs of the following equations

(1) $2x+7y=10$ (2) $4x-5y-7=0$

(3) $5x+6y+8=0$ (4) $-3x+7y+8=0$

(5) $10y-9x=13$ (6) $8x-11y+13=0$

5. Draw the graphs of the following equations

(1) $\frac{x}{3}+\frac{y}{4}=1$ (2) $\frac{x}{7}+\frac{y}{-9}=1$ (3) $\frac{x}{-8}+\frac{y}{13}=1$

(4) $y=\frac{5-7x}{6}$. (5) $y=\frac{9x-13}{4}$. (6) $\frac{3x}{4}-\frac{4y}{3}=1$

6. Draw the graphs of the following expressions

(1) $x-3$ (2) $3x+4$ (3) $-7x+8$

(4) $\frac{7-4x}{3}$. (5) $\frac{5x-9}{4}$. (6) $\frac{8x+11}{5}$.

7. Find the equation of the straight line which passes through each of the following pairs of points

(1) (0, 0), (5, 6) (2) (0, 5), (7, 0)

(3) (6, −8), (−7, 5) (4) (−4, 8), (−9, −13)

(5) (−11, 0), (7, −10)

CHAPTER XX

EASY QUADRATIC EQUATIONS AND PROBLEMS

122. Definition. Any equation which contains the square of the unknown quantity, but no higher power, is called a **quadratic equation** or an **equation of the second degree.**

If an equation contains *only* the second power of the unknown quantity (and *not* the *first*) it is called a **pure** quadratic, if it contains the second *as well as* the first power it is called an **adfected** quadratic

Thus $\qquad 3x^2=75$ is a pure quadratic,

and $\qquad 3x^2-7x=6$ is an adfected quadratic

123. Solution of a Pure Quadratic. In solving a Pure Quadratic we have to find the *square of the unknown quantity* just in the same way as simple equations are solved and then to extract the square root of the value so found

Example 1. Solve $5(x^2+1)-2=3(x^2+7)$

We have $\qquad 5x^2+3=3x^2+21,$

hence $\qquad 2x^2=18 \qquad$ [by transposition]

$$x^2=9;$$

now, since the unknown quantity is one of which the square is 9, it must be *either* $+3$ *or* -3 (Thus there are *two* values of x satisfying the given equation, as the student can easily verify)

Note *The student should carefully observe that the last step of the above solution amounts to answering the following question "What quantity is that of which the square is 9"?*

Example 2. Solve $\frac{1}{3}(x-2)(x-3)-\frac{1}{21}(x-21)(x-14)=2$

Multiplying both sides by 21 we have

$$7(x-2)(x-3)-(x-21)(x-14)=42$$

The left side $=(7x^2-35x+42)-(x^2-35x+294)$

$$=7x^2-35x+42-x^2+35x-294$$

$$=6x^2-252$$

Hence, the equation reduces to

$$6x^2 - 252 = 42$$

or $\quad 6x^2 = 252 + 42$ [by transposition]

i e, $= 294$

Dividing both sides by 6, we have

$$x^2 = 49$$

Now, the unknown quantity is such that its square is 49, it must be *either* +7 *or* −7

Hence, $x =$ *either* $+7$ *or* -7

Example 3. Find the side of a square whose area is equal to that of a rectangle of length 9 yards and breadth 4 yards

Let the side of the square $= x$ yds

The area of the square $= x \times x$ sq yds

$= x^2$ sq yds

Again, the area of the rectangle

$= 4 \times 9$ sq yds

$= 36$ sq yds

Hence, by the condition of the problem,

x^2 sq yds $= 36$ sq yds

or, $\quad x^2 = 36$,

$\therefore \quad x = 6$, or, -6

Since, the actual length of the side of a square is a positive quantity, the solution $x = -6$ is inadmissible

$\therefore$ the required side $= 6$ yds

N B. In problems leading to quadratic equations, the solutions which are found inadmissible by the condition of the problem should be rejected

EXERCISE 68.

Find the values of x in each of the following equations

1. $3x^2 = 27$ **2.** $a^2x^2 = a^4$ **3.** $\frac{1}{7}x^2 = 28$

4. $8x + \frac{7}{x} = \frac{65}{7}x$ **5.** $2(x^2 - 5) + x(3 - x) = 3(x + 5)$

6. $(x-7)(x-10) + (x-3)(x-2) = (x-17)(x-5)$

7. $\frac{2x^2+10}{15} = 7 - \frac{50+x^2}{25}$.

8. $(x+a)^2-2a(a+x)=3a^2$

9. $x^2+2bx-b^2=a^2-b(b-2x)$

10. $2x(3x+5)-5x(x+2)=36$

11. $\frac{3x^2+15}{7}+\frac{2x^2+9}{3}=\frac{2x^2+87}{21}+2$

12. Find the number four times which is equal to sixteen times its reciprocal

13. Find the side of a square three times the area of which is equal to four times the area of a rectangle whose length and breadth are respectively 9 yards and 3 yards

14. A has got a square plot of land which he exchanges with a rectangular garden of area 91 sq yds, belonging to B and gains by the transaction an area of 10 sq yds Find a side of the square plot

15. Divide a straight line of length 10 ft into two portions such that five times the square on one exceeds the square on the other by twenty times the former portion

121. Solution of a Quadratic by the method of resolution into factors. Reducing a Quadratic to the form $ax^2+bx+c=0$, if we know the factors of which the left-hand side is the product, then by equating to zero either of these factors, we get a solution of the quadratic

Example 1. Solve $x^2-5x+6=0$

Evidently the left-hand side $=(x-2)(x-3)$

Hence we have

$$(x-2)(x-3)=0$$

$$\therefore \text{ either } \left.\begin{array}{r} x-2=0 \\ \text{and } x=2 \end{array}\right\} \text{ or } \left.\begin{array}{r} x-3=0 \\ \text{and } x=3 \end{array}\right\}$$

Thus 2 and 3 are the roots of the equation, as the student can easily verify

Example 2. Solve $2x^2-10x=3x-15$

We have $$2x(x-5)=3(x-5) \qquad (1)$$

$$(2x-3)(x-5)=0$$

Hence either $\left.\begin{aligned} 2x-3&=0 \\ \text{and } \therefore \quad x&=\tfrac{3}{2}\end{aligned}\right\}$ or $\left.\begin{aligned} x-5&=0 \\ \text{and} \quad x&=5\end{aligned}\right\}$

Thus $\frac{3}{2}$ and 5 are the roots of the equation

Note *The solution also follows at once from equation (1), for $x-5$ being a factor common to both sides the equation evidently holds good when this factor is zero, i.e., when $x=5$, and evidently also, the equation is satisfied when $2x=3$, or $x=\frac{3}{2}$, therefore 5 and $\frac{3}{2}$ are the roots of the equation The student will thus observe that it is not always necessary to transpose all the terms to the left-hand side of the equation*

Example 3. Solve $10(2x+3)(x-3)+(7x+3)^2=20(x+3)(x-1)$

We have, $10(2x^2-3x-9)+(49x^2+42x+9)=20(x^2+2x-3)$,

$$\therefore \quad 49x^2-28x-21=0$$

$$\therefore \quad 7x^2-4x-3=0,$$

$$\text{or,} \quad (7x^2-7x)+(3x-3)=0$$

$$\text{or,} \quad (7x+3)(x-1)=0$$

Hence, either $\left.\begin{aligned} 7x+3&=0 \\ \text{and } \therefore \quad x&=-\tfrac{3}{7}\end{aligned}\right\}$ or, $\left.\begin{aligned} x-1&=0 \\ \text{and} \quad x&=1\end{aligned}\right\}$

Thus $-\frac{3}{7}$ and 1 are the roots of the equation

Example 4. Find the number which exceeds sixty-five times its reciprocal by 64

Let x be the required number

Then, by the condition of the problem

$$x-\frac{65}{x}=64$$

Multiplying both sides by x, we have

$$x^2-65=64x$$

$$\text{or,} \quad x^2-64x-65=0, \qquad \text{[by transposition]}$$

$$\text{or,} \quad (x-65)(x+1)=0, \qquad \text{[by factorisation]}$$

$\therefore$ either $\left.\begin{aligned} x-65&=0 \\ \text{i e,} \quad x&=65\end{aligned}\right\}$ or, $\left.\begin{aligned} x+1&=0 \\ \text{i e,} \quad x&=-1\end{aligned}\right\}$

Hence the required number is either 65 or -1

EXERCISE 69.

Solve the following equations

1. $3x^2-12x+1=6x-23$
2. $4x^2-4x=80$
3. $x+2-\dfrac{6}{x+2}=1$
4. $x^2+9x-52=0$
5. $x^2-\frac{5}{3}x-4=0$
6. $6x^2+5x-4=0$
7. $3(x-2)^2=18+(8x+1)$
8. $x-\dfrac{x^3-8}{x^2+5}=2$
9. $\dfrac{21x^3-16}{3x^2-4}-7x=5$
10. $x^2-(a+b)x+ab=0$

11. Find two numbers whose product is equal to 399 and sum is equal to 40

12. Find the number whose square exceeds ten times itself by 96

13. Find the number which exceeds 12 by as much as thirty-nine times its reciprocal falls short of 4

14. The difference between the ages of a man and his son is 25 now If the product of the numbers denoting their ages, ten years back, be 150, find the present age of the father

15. The length of a rectangular garden of area, 100 sq yds exceeds its breadth by 15 yards Find the cost of fencing it by wire-net the price of which is 8 annas per foot

Miscellaneous Exercises. IV

I

1. Define *Highest Common Factor* and *Lowest Common Multiple* of two or more algebraical expressions Find the H C F and L C M of $36x^2a^4c^5$, $24xy^2a^3b^4$ and $240y^3a^6b^2c$

2. Factorise the following expressions and find their H C F : x^2-6x+9 and $4x^2-11x-3$

3. Find the L C M of
$$ab-ac-b^2+bc \text{ and } b^2-12ac-4a^2-9c^2$$

4. Resolve $x^3+y^3+3xy-1$ into elementary factors and show that the H C F of this and $2(x^2+xy-x)+3y(x+y)-(7+3y)+7x+7y$ is $x+y-1$

5. If $2s=a+b+c$, show that

$$\frac{2bc+(b^2+c^2-a^2)}{2bc-(b^2+c^2-a^2)}=\frac{s(s-a)}{(s-b)(s-c)}.$$

6. Reduce the following to its simplest form

$$\frac{x^6}{x^2-1}-\frac{x^4}{x^2+1}-\frac{1}{x^2-1}+\frac{1}{x^2+1}.$$

7. Solve $ax+1=by+1=ay+bx$

8. One pipe can fill a cistern in a hours, another can do it in b hours, in what time could the two running together fill it? And if a third pipe could empty the cistern in c hours, how long would it take to do this if the first two were running at the same time?

II

1. Find the H C F of

$$7x^2-26x+15 \text{ and } 5x(x-1)+3(3x-11)-24$$

2. Find the L C M of

$$x^3+bx^2+ax+ab \text{ and } x^2-(a-b)x-ab$$

3. Reduce the following to its simplest form

$$\text{(i) } \frac{(3x^4y^2-3x^2y^4)^2}{(2x^3y-2xy^3)^2}; \quad \text{(ii) } \frac{3(x^2-x-30)(x^2-9x+14)}{(x^2-13x+42)(x^2+3x-10)}.$$

4. Find the value of

$$\frac{x+y}{x-y}+\frac{x-y}{x+y}, \text{ when } x=a^2+b^2 \text{ and } y=a^2-b^2$$

5. Simplify $\dfrac{(2x-9)^2-(x-6)^2}{3(x^2-10x+25)}+\dfrac{2(x-3)^2}{3(x^2-8x+15)}.$

6. Show that

$$\frac{x^4}{3}-\frac{11}{12}x^3+\frac{41x^2}{8}-\frac{23x}{4}+6 \text{ contains } \frac{2x^2}{3}-\frac{5x}{6}+1 \text{ as a factor.}$$

7. Find the value of x when

$$\frac{5}{7}(2x-11)-\frac{3}{4}(x-5)=\frac{x}{3}-(10-x)$$

8. Solve $ax+by=c^2$ and $\dfrac{a+x}{b}-\dfrac{b+y}{a}=0$

III.

1. Find the H C F of $a^2x^3+a^5-2abx^3+b^2x^3+a^3b^2-2a^4b$ and $2a^2x^4-5a^4x^2+3a^6-2b^2x^4+5a^2b^2x^2-3a^4b^2$.

2. Find the L C M of $x^5+x^4+x^3+x^2+x+1$ and $x^5-x^4+x^3-x^2+x-1$

3. Find the H C F of x^2-9, $(x+3)^2$ and x^2+x-6 [C U 1910]

4. State and prove the rule for finding the Lowest Common Multiple of two algebraical expressions [B U 1902]

Find the L C M of $x^2+(a+b)x+ab$, x^2-b^2 and $x^2+(a-b)x-ab$

5. Simplify $\frac{1}{4}\cdot\left(\frac{x+3}{x^2+x-6}-\frac{x-5}{x^2-3x-10}\right)-\frac{1}{x^2+4}$.

6. Solve $ax+y=x+by=\frac{1}{2}(x+y)+1$

7. An income of £196 is derived from two sums invested, one at 4 per cent, the other at 7 per cent per annum; if the interest on the former had been 5 per cent, and on the latter 6 per cent, the income derived would have been £212 Find the sums invested

8. Find the value of x when $3(x^2-4)=15$

IV

1. Define H C F and L C M of two or more algebraical expressions

If H and L denote the H C F. and L C M respectively of two algebraical expressions A and B, show that

$$H\times L=A\times B.$$

2. Find the H C F of x^2-y^2, $x^2-2xy+y^2$ and x^3-y^3, and show that when their L C M is divided by x^2+xy+y^2 the quotient is $(x-y)(x^2-y^2)$

3. Find the defect of $\frac{x+6}{x^2+5x-6}$ from $\frac{x+5}{x^2+3x-10}$.

4. Simplify $\frac{1}{m^2+m+1}+\frac{2m}{m^4+m^2+1}$.

5. Show that $(x+y)^3-(y+z)^3$
$$=3(x-z)\{(x+y)(y+z)+\tfrac{1}{3}(x-z)^2\}$$

6. A number of three digits has 5 in the units' place and the middle figure is half the sum of the other two, if 108 be added to the number the hundreds' figure will take the place of the units' and the units' the place of the tens' Find the number

7. If 3 be added to the numerator and denominator of a certain fraction, the fraction becomes $\frac{2}{3}$, if 5 be subtracted from the numerator and denominator, it becomes $\frac{1}{2}$ Find the fraction

8. Solve $5(x^2-3x+11)+3(x^2+2x+4)=3(3x^2-3x+1)$

V

1. Find the H C F of $x^4-(a^2+b^2)x^2+a^2b^2$ and $x^4-(a+b)^2x^2+2ab(a+b)x-a^2b^2$

2. Find the L C M of $35x^2-11x-6$ and $40x^2-29x+3$

3. Reduce to simplest form
$$\left\{\frac{2x}{x+y}-\frac{x^2}{x^2-y^2}+\frac{2y}{x-y}\right\}\times\left(\frac{1}{x}+\frac{1}{y}\right)\div\left\{\frac{3}{x-y}-\frac{2}{x}+\frac{1}{y}\right\}.$$

4. Simplify $\dfrac{a^2+bc+ca+ab}{a^2+2bc+2ca+ab}\times\dfrac{a^3+8c^3}{a^4+a^2c^2+6ac^3+4c^4}.$

5. Show that
$$\frac{x+2}{1+x+x^2}-\frac{x-2}{1-x+x^2}-\frac{2x^2-4}{1-x^2+x^4}=\frac{4x^4+8}{x^8+x^4+1}.$$

6. A and B travel together 120 miles by rail A takes a return ticket for which he has to pay one fare and a half Coming back they find that A has travelled cheaper than B by 4 annas 2 pies for every 100 miles Show that the fare per mile is 2 pies

7. The expression $ax+b$ is equal to 13 when x is 5, and to 29 when x is 13 Show that the value of the expression is 4 whan x is 5

8. The defect of 4 from twice the square of a number is 28 Find the number

VI

1. Find the H C F of

$$3x^3-18x^2+33x-18,\ x^2-5x+6 \text{ and } x^2-3x+2$$

2. Find the L C M of $ax^2-(a^2+ab)x+a^2b$, $bx^2-(b^2+bc)x+b^2c$ and $cx^2-(c^2+ac)x+c^2a$

3. There are two quantities a and b of which the L C M is x, and the G C M is y, if $x+y=ma+\frac{b}{m}$, show that $x^3+y^3=m^3a^3+\frac{b^3}{m^3}$.

4. Simplify $\frac{z(x^3-y^3)}{x^2+xy+y^2}+\frac{x(y^3-z^3)}{y^2+yz+z^2}+\frac{y(z^3-x^3)}{z^2+zx+x^2}$.

5. If $x=\frac{a}{a+b}$ and $y=\frac{b}{a+b}$, show that

(i) $\frac{x^2+y^2}{x^2-y^2}=\frac{a^2+b^2}{a^2-b^2}$, (ii) $\frac{x^3-y^3}{x^3+y^3}=\frac{a^3-b^3}{a^3+b^3}$.

6. Solve

$$\tfrac{1}{3}(7x-5)+\tfrac{1}{39}(34x+10)-\frac{(3x-2)(5x-3)}{4}=\frac{(4-x)(2+15x)}{4}-18$$

7. A market-woman bought apples at three for a penny and as many more at four for a penny, and thinking to make her money again, she sold them at seven for 2d She lost however, 3d by the business How much did she sell them for?

8. Solve $(2x+3)(x-5)+(x+5)(3x+1)=34+(x+4)(x+5)$

VII

1. Find the H C F of $x^3-7x^2+5x-35$, x^4+8x^2+15 and $x^3(x^2+8)-7(x^4+15)+15x-56x^2$

2. Find the L C M of $ab-ac+bc-b^2$, $bc-ab+ac-c^2$ and $ac-bc+ab-a^2$

3. The H C F and L C M of two numbers x and y are respectively 3 and 105, if $x+y=36$, prove that

$$\frac{1}{x}+\frac{1}{y}=\frac{4}{35}$$

4. Simplify $\frac{1}{(x-1)(x-2)}+\frac{1}{(x-2)(x-3)}+\frac{1}{(x-3)(x-1)}$.

5. Find the value of $\frac{x+y}{x-y}$, when $x=\frac{a+b}{a-b}$ and $y=\frac{a-b}{a+b}$.

6. Show that if a number formed by two digits is four times the sum of its digits, the number formed by interchanging the digits is seven times their sum

7. Solve $\left.\begin{aligned} 3x+20 &= 4y-10 \\ 4(x-1)-3(y-3) &= 0 \end{aligned}\right\}$ [C U 1895]

8. Find the number, the square of which exceeds 7 by as much as the square of half the number falls short of 13

CHAPTER XXI

HARDER FORMULÆ

We shall now consider some important formulæ of a somewhat harder type than those treated of in Chapter IV

125. Formula $(x+a)(x+b)(x+c)$
$$=x^3+(a+b+c)x^2+(bc+ca+ab)x+abc$$

Note *The student can easily verify this. It is also evident that the following results are included in it*

$$(x-a)(x-b)(x-c)=x^3-(a+b+c)x^2+(bc+ca+ab)x-abc,$$
$$(x+a)(x+b)(x-c)=x^3+(a+b-c)x^2-(bc+ca-ab)x-abc,$$
$$(x+a)(x-b)(x-c)=x^3+(a-b-c)x^2+(bc-ca-ab)x+abc.$$

For instance,

$$\begin{aligned}(x-a)(x-b)(x-c)&=\{x+(-a)\}\{x+(-b)\}\{x+(-c)\}\\ &=x^3+\{(-a)+(-b)+(-c)\}x^2+\{(-b)(-c)\\ &\quad+(-c)(-a)+(-a)(-b)\}x+(-a)(-b)(-c)\\ &=x^3-(a+b+c)x^2+(bc+ca+ab)x-abc.\end{aligned}$$

Similarly, the other two results can be established, which is left as an exercise for the student

Example 1. Write down the product of $x+2, x+4$ and $x+6$

$$2+4+6=12,$$
$$4\times 6+6\times 2+2\times 4=24+12+8=44,$$
$$2\times 4\times 6=48$$

Hence, the required product $=x^3+12x^2+44x+48$

Example 2. Write down the product of $x-3, x-5$ and $x-7$

$$(-3)+(-5)+(-7)=-15,$$
$$(-5)(-7)+(-7)(-3)+(-3)(-5)=35+21+15=71,$$
$$(-3)(-5)(-7)=-105$$

Hence the required product $=x^3-15x^2+71x-105$

Example 3. Write down the product of $x-4, x+5$ and $x-3$

$$(-4)+5+(-3)=-2,$$
$$(5)(-3)+(-3)(-4)+(-4)(5)=-15+12-20=-23,$$
$$(-4)\times 5\times(-3)=60$$

Hence, the required product $=x^3-2x^2-23x+60$

Example 4. Write down the product of $x+3, x+5$ and $x-8$

$$3+5+(-8)=0,$$
$$(5)(-8)+(-8)(3)+(3)(5)=-40-24+15=-49,$$
$$3\times 5\times(-8)=-120$$

Hence, the required product $=x^3-0\,x^2-49x-120$
$=x^3-49x-120$

EXERCISE 70.

Write down the product of

1. $x+1, x+2$ and $x+3$
2. $x+2, x+5$ and $x+7$
3. $x+3, x-6$ and $x+2$
4. $x+4, x+5$ and $x-10$
5. $x-8, x+3$ and $x+1$
6. $x-5, x-2$ and $x+8$.
7. $x-3, x+7$ and $x-4$
8. $x+6, x-5$ and $x-7$
9. $x-5$ $x-7$ and $x-11$
10. $x-3, x-6$ and $x-9$

11. $x+4, x-5$ and $x-12$

12. $x+5, x+9$ and $x+11$

13. $x-6, x+8$ and $x-2$

14. $x-3, x-7$ and $x-13$

15. $x-3, x+12$ and $x+4$

16. $x-9, x-10$ and $x+12$

17. $x+9, x-5$ and $x-7$

18. $x+8, x+12$ and $x+15$

19. $x-14, x+8$ and $x+6$

20. $x-5, x-10$ and $x-16$

126. Squares of multinomials. It has been respectively shown in examples 4 and 5 of Art 54 that $(a+b+c)^2=a^2+b^2+c^2+2ab+2ac+2bc$ and $(a+b+c+d)^2=a^2+b^2+c^2+d^2+2ab+2ac+2ad+2bc+2bd+2cd$

Thus in each of these cases we may observe that the square of the whole expression is obtained by taking the sum of the squares of the different terms and of twice the product of each term by every term which *follows* it The results are best remembered when put as follows

$$(a+b+c)^2=a^2+b^2+c^2+2a(b+c)+2bc,$$
$$(a+b+c+d)^2=a^2+b^2+c^2+d^2+2a(b+c+d)+2b(c+d)+2cd$$

The same rule may be shown to hold in every other case, for instance, let us find the square of $a+b+c+d+e$

We have
$$\begin{aligned}(a+b+c+d+e)^2&=\{(a+b+c)+(d+e)\}^2\\ &=(a+b+c)^2+2(a+b+c)(d+e)+(d+e)^2\\ &=\{a^2+b^2+c^2+2a(b+c)+2bc\}+\{2a(d+e)+2b(d+e)\\ &\qquad+2c(d+e)\}+(d^2+e^2+2de)\\ &=a^2+b^2+c^2+d^2+e^2+2a(b+c+d+e)\\ &\qquad+2b(c+d+e)+2c(d+e)+2de\end{aligned}$$

Hence, we conclude that the square of any multinomial is equal to the sum of the squares of its different terms together with twice the product of each term by every term which *follows* it

It is needless to add that the above rule will also hold good when the multinomial under consideration contains one or more negative terms, for the symbols used above are perfectly general in character and any of them may stand either for a positive or a negative quantity

Note *Since* $(a+b+c)^2=a^2+b^2+c^2+2(ab+ac+bc)$, *we have*

$$\begin{aligned}2(ab+ac+bc)&=\{a^2+b^2+c^2+2(ab+ac+bc)\}-(a^2+b^2+c^2)\\ &=(a+b+c)^2-(a^2+b^2+c^2)\end{aligned}$$

Similarly, $a^2+b^2+c^2=(a+b+c)^2-2(ab+ac+bc)$

Example 1. Write down the square of $x-y+z-v$

$$\begin{aligned}(x-y+z-v)^2 &= x^2+y^2+z^2+v^2+2x(-y+z-v)\\ &\qquad +2(-y)(z-v)+2z(-v)\\ &= x^2+y^2+z^2+v^2-2xy+2xz-2xv\\ &\qquad -2yz+2yv-2zv\end{aligned}$$

Example 2. Write down the square of $-a+2b-3c-d$

$$\begin{aligned}(-a+2b-3c-d)^2 &= a^2+4b^2+9c^2+d^2+2(-a)(2b-3c-d)\\ &\qquad +2(2b)(-3c-d)+2(-3c)(-d)\\ &= a^2+4b^2+9c^2+d^2-4ab+6ac+2ad\\ &\qquad -12bc-4bd+6cd\end{aligned}$$

Example 3. Find the value of $a^2+b^2+c^2+2ab-2ac-2bc$, when $a=19$, $b=18$ and $c=32$

The given expression $=a^2+b^2+c^2+2a(b-c)+2b(-c)$
$=(a+b-c)^2$

Hence the reqd value $=(19+18-32)^2$
$=(5)^2=25$

Example 4. If $x=b+c$, $y=c-a$, $z=a-b$, prove that $x^2+y^2+z^2-2xy-2xz+2yz=4b^2$. [C U Entr Paper, 1883.]

$$\begin{aligned}&x^2+y^2+z^2-2xy-2xz+2yz\\ &\qquad = x^2+y^2+z^2+2x(-y-z)+2(-y)(-z)\\ &\qquad = (x-y-z)^2\\ &\qquad = \{(b+c)-(c-a)-(a-b)\}^2\\ &\qquad = (2b)^2=4b^2\end{aligned}$$

EXERCISE 71.

Write down the square of ·

1. $x+y-z$ **2.** $x-y+z$ **3.** $-x+y+z$

4. $-x-y+z$ **5.** $x-y-z$ **6.** $a-x+y-z$

7. $a-x-y-z$ **8.** $m+n+p+q+r$ **9.** $p-q+r-x-y$

10. $-a+b-c+x-y-z$ **11.** $a-2x-3y-4z$.

12. $2a-b+2c-d$.

Find the value of

13. $l^2+m^2+n^2-2lm+2ln-2mn$, when $l=17$, $m=23$ and $n=13$

14. $p^2+q^2+r^2+2pq-2pr-2qr$, when $p=16$ $q=12$ and $r=25$

15. $a^2+b^2+c^2-2ab-2ac+2bc$ when $a=28$, $b=13$ and $c=15$

16. $x^2+y^2+1+2xy-2x-2y$, when $x=6$ and $y=7$

17. $x^2+y^2+2xy-2x-2y+36$, when $x=23$ and $y=18$

18. $x^2+4y^2+1-4xy-2x+4y$, when $x=26$ and $y=12$

19. $x^2+9y^2-6xy-2x+6y+64$ when $x=49$ and $y=16$

20. $9x^2+y^2-6xy+6x-2y-24$, when $x=14$ and $y=38$

21. If $a+b+c=12$ and $a^2+b^2+c^2=50$, find the value of $ab+ac+bc$

22. If $a+b+c=13$ and $ab+ac+bc=50$, find the value of $a^2+b^2+c^2$

127. Powers of Binomials : Involution.

By actual multiplication it may be seen that

$$\left.\begin{aligned}(a+b)^2&=a^2+2ab+b^2\\(a-b)^2&=a^2-2ab+b^2\end{aligned}\right\}$$

$$\left.\begin{aligned}(a+b)^3&=a^3+3a^2b+3ab^2+b^3\\(a-b)^3&=a^3-3a^2b+3ab^2-b^3\end{aligned}\right\}$$

$$\left.\begin{aligned}(a+b)^4&=a^4+4a^3b+6a^2b^2+4ab^3+b^4\\(a-b)^4&=a^4-4a^3b+6a^2b^2-4ab^3+b^4\end{aligned}\right\}$$

$$\left.\begin{aligned}(a+b)^5&=a^5+5a^4b+10a^3b^2+10a^2b^3+5ab^4+b^5\\(a-b)^5&=a^5-5a^4b+10a^3b^2-10a^2b^3+5ab^4-b^5\end{aligned}\right\}$$

$$\left.\begin{aligned}(a+b)^6&=a^6+6a^5b+15a^4b^2+20a^3b^3+15a^2b^4+6ab^5+b^6\\(a-b)^6&=a^6-6a^5b+15a^4b^2-20a^3b^3+15a^2b^4-6ab^5+b^6\end{aligned}\right\}$$

Note *On examining the above cases we observe that*

(1) The total number of terms in the resulting expression is one more than the index of the binomial Thus in the ***fifth*** *power the number of terms is* ***six****, in the* ***sixth*** *power the number of terms is* ***seven*** *; and so on*

(2) Any power of $a-b$ differs from the same power of $a+b$ **only** *in this that the signs of the terms of the former are* **alternately** *$+$ and $-$, whilst those of the latter are* **all** *$+$*

(3) The first term is a raised to a power equal to that of the binomial, and the last term is b raised to the same power Thus, in the **fourth** *power, the first term is a^4 and the last b^4, in the* **fifth** *power, the first term is a^5 and the last b^5, and so on As to the other terms the power of a in any term is one less, whilst the power of b is one greater than that in the preceding term*

(4) The co-efficient of the second term is the same as the index of the power to which the binomial is raised, and if the co-efficient of any term be multiplied by the index of a in that term and divided by the number **indicating the position** *of that term, the result gives the co-efficient of the next term Thus, if we multiply the co-efficient of the* **second** *term by the index of a in it and divide the product by* **two**, *we get the co-efficient of the 3rd term, again, if the co-efficient of the* **third** *term be multiplied by the index of a in it and the product divided by* **three**, *we obtain the co-efficient of the 4th term, and so on*

(5) The co-efficients of the terms equidistant from the beginning and the end are the same, in other words, the co-efficient of the term which has any number of terms **before** *it is equal to that of the term which has the same number of terms* **after** *it*

The laws observed above, a proof of the universal truth of which is beyond the scope of our limits, furnish us with a ready means of raising a binomial to any power without the process of actual multiplication The following examples are intended to illustrate the application of those laws

[The resulting expression in each case is called the **expansion** *of the corresponding power of the binomial]*

The operation of raising any expression to any power is called ***Involution.***

Example 1. Raise $a+b$ to the *seventh* power

The total number of terms in the expansion $=8$

$$\left.\begin{array}{lll} \text{The first term} & & = a^7 \\ \quad \text{,,}\ \ \text{2nd} & \text{,,} & = 7a^6b \\ \quad \text{,,}\ \ \text{3rd} & \text{,,} & = \frac{7\times 6}{2}a^5b^2 = 21a^5b^2 \\ \quad \text{,,}\ \ \text{4th} & \text{,,} & = \frac{21\times 5}{3}a^4b^3 = 35a^4b^3 \end{array}\right\} \text{[Laws (3) and (4)]}$$

Now, since the four terms from the end will have respectively the same co-efficients as the four terms from the beginning [law (5)], the next four terms of the expansion will respectively be $35a^3b^4$, $21a^2b^5$, $7ab^6$ and b^7

Hence, we have $$(a+b)^7 = a^7 + 7a^6b + 21a^5b^2 + 35a^4b^3 + 35a^3b^4 + 21a^2b^5 + 7ab^6 + b^7.$$

Example 2. Expand $(x-y)^8$

The total number of terms in the expansion $=9$

$$\left.\begin{array}{lll} \text{The first term} & = x^8 & \\ \quad\text{,, 2nd ,,} & = -8x^7y & \\ \quad\text{,, 3rd ,,} & = \frac{8\times7}{2}x^6y^2 & = 28x^6y^2 \\ \quad\text{,, 4th ,,} & = -\frac{28\times6}{3}x^5y^3 & = -56x^5y^3 \\ \quad\text{,, 5th ,,} & = \frac{56\times5}{4}x^4y^4 & = 70x^4y^4 \end{array}\right\} \text{[Laws (2), (3) and (4)]}$$

The co-efficients of the remaining four terms need not be calculated as the co-efficients of the first four terms only will now reappear in the reverse order [Law (5)]

Hence, we have
$$(x-y)^8 = x^8 - 8x^7y + 28x^6y^2 - 56x^5y^3 + 70x^4y^4 - 56x^3y^5 + 28x^2y^6 - 8xy^7 + y^8$$

Example 3. Expand $(2x-3y)^7$

The total number of terms in the expansion $=8$

As we have $2x$ for a and $3y$ for b, we must have

$$\left.\begin{array}{lll} \text{The first term} & = (2x)^7 & \\ \quad\text{,, 2nd ,,} & = -7(2x)^6(3y) & \\ \quad\text{,, 3rd ,,} & = \frac{7\times6}{2}(2x)^5(3y)^2 & = 21(2x)^5(3y)^2 \\ \quad\text{,, 4th ,,} & = -\frac{21\times5}{3}(2x)^4(3y)^3 & = -35(2x)^4(3y)^3 \end{array}\right\}$$

We can now write down the remaining four terms which will respectively be $35(2x)^3(3y)^4$, $-21(2x)^2(3y)^5$, $7(2x)(3y)^6$ and $-(3y)^7$.

Hence, we have
$$\begin{aligned}(2x-3y)^7 &= (2x)^7 - 7(2x)^6(3y) + 21(2x)^5(3y)^2 - 35(2x)^4(3y)^3 \\ &\quad + 35(2x)^3(3y)^4 - 21(2x)^2(3y)^5 + 7(2x)(3y)^6 - (3y)^7 \\ &= 128x^7 - 7(64x^6)(3y) + 21(32x^5)(9y^2) - 35(16x^4)(27y^3) \\ &\quad + 35(8x^3)(81y^4) - 21(4x^2)(243y^5) + 7(2x)(729y^6) - 2187y^7 \\ &= 128x^7 - 1344x^6y + 6048x^5y^2 - 15120x^4y^3 + 22680x^3y^4 \\ &\quad - 20412x^2y^5 + 10206xy^6 - 2187y^7\end{aligned}$$

Example 4. Find the value of

$x^6+6x^5+15x^4+20x^3+15x^2+6x-8$, when $x=\sqrt[3]{3}-1$

The given expression

$$=(x^6+6x^5+15x^4+20x^3+15x^2+6x+1)-9$$
$$=(x+1)^6-9$$
$$=(\sqrt[3]{3})^6-9=9-9=0$$

EXERCISE 72.

Expand

1. $(x+1)^5$ **2.** $(x+1)^6$ **3.** $(a+b)^8$ **4.** $(a+b)^9$

5. $(x-y)^5$ **6.** $(m-n)^7$ **7.** $(x+2)^4$ **8.** $(x+2)^5$

9. $(x+1)^8$ **10.** $(x+3)^4$ **11.** $(x-1)^5$ **12.** $(2-z)^6$

13. $(2x-1)^4$ **14.** $(x-y)^9$ **15.** $(3x-2)^5$ **16.** $(1-a)^8$

17. $(1-c)^7$ **18.** $(1-3x)^6$ **19.** $(1-2x)^7$ **20.** $(2x-a)^8$

21. $(x-a)^{10}$ **22.** $(3x-2a)^5$

Simplify

23. $(x+1)^5-(x-1)^5$ **24.** $(x-1)^6+(x+1)^6$

25. $(x+a)^7-(x-a)^7$

Find the sum of the co-efficients in the expansion of

26. $(x+a)^4$ **27.** $(x+a)^5$ **28.** $(x+a)^6$

29. $(x+a)^7$ **30.** $(x+a)^8$

Find the value of

31. $x^5+5x^4+10x^3+10x^2+5x+32$, when $x=-2$

32. $x^6-6x^5+15x^4-20x^3+15x^2-6x$, when $x=\sqrt[3]{2}+1$

33. $16x^4-32x^3+24x^2-8x-80$, when $x=2$

34. $x^4+12x^3+54x^2+108x+81$, when $x=-5$

35. $x^4+8x^3+24x^2+32x-609$, when $x=-7$

128. Formula $(a+b+c)(a^2+b^2+c^2-bc-ca-ab)$

$$=\tfrac{1}{2}(a+b+c)\{(b-c)\ +(c-a)^2+(a-b)^2\}$$
$$=a^3+b^3+c^3-3abc$$

$$[(a+b+c)(a^2+b^2+c^2-bc-ca-ab)$$
$$=(a+b+c)\{(a^2+b^2-ab)-(ac+bc)+c^2\}$$
$$=(a+b+c)\{\overline{(a+b)^2-3ab}-c(a+b)+c^2\}$$
$$=(\overline{a+b}+c)\{\overline{(a+b)^2-c(a+b)+c^2}-3ab\}$$
$$=\overline{(a+b)^3+c^3}-3ab(\overline{a+b}+c)$$
$$=(a+b)^3-3ab(a+b)+c^3-3abc$$
$$=a^3+b^3+c^3-3abc]$$

Cor. Conversely, $a^3+b^3+c^3-3abc=(a+b+c)(a^2+b^2+c^2-bc-ca-ab)$ Hence, we can always resolve an expression into factors whenever it is of the form $a^3+b^3+c^3-3abc$

Note *Since* $a^2+b^2+c^2-bc-ca-ab=\frac{1}{2}\{(b-c)^2+(c-a)^2+(a-b)^2\}$, *we have* $a^3+b^3+c^3-3abc=\frac{1}{2}(a+b+c)\{(b-c)^2+(c-a)^2+(a-b)^2\}$

Example 1. Multiply $x^2+y^2+z^2+xy+xz-yz$ by $x-y-z$

Putting a for x, b for $-y$ and c for $-z$, we have

$$(x-y-z)(x^2+y^2+z^2+xy+xz-yz)$$
$$=(a+b+c)(a^2+b^2+c^2-ab-ac-bc)$$
$$=a^3+b^3+c^3-3abc$$
$$=x^3-y^3-z^3-3xyz$$

Example 2. Resolve $m^3-n^3+1+3mn$ into factors

Putting a for m, b for $-n$ and c for 1, we have

$$m^3-n^3+1+3mn=a^3+b^3+c^3-3abc$$
$$=(a+b+c)(a^2+b^2+c^2-ab-ac-bc)$$
$$=(m-n+1)(m^2+n^2+1+mn-m+n)$$

Example 3. Show that $(x-y)^3+(y-z)^3+(z-x)^3$
$$=3(x-y)(y-z)(z-x)$$

Putting a for $x-y$, b for $y-z$ and c for $z-x$, we have

$$a+b+c=(x-y)+(y-z)+(z-x)=0$$

Hence, $\{(x-y)^3+(y-z)^3+(z-x)^3\}-3(x-y)(y-z)(z-x)$

$$=a^3+b^3+c^3-3abc$$
$$=(a+b+c)(a^2+b^2+c^2-ab-ac-bc)$$
$$=0\times(a^2+b^2+c^2-ab-ac-bc)$$
$$=0,$$
$$(x-y)^3+(y-z)^3+(z-x)^3=3(x-y)(y-z)(z-x)$$

EXERCISE 73.

Multiply

1. $x^2+y^2+z^2-xy+xz+yz$ by $x+y-z$

2. $p^2+4q^2+r^2+2pq+pr-2qr$ by $p-2q-r$

3. $4x^2+9y^2+z^2+6xy+2xz-3yz$ by $2x-3y-z$

4. $a^2+4b^2+2ab-3a+6b+9$ by $a-2b+3$

5. $9a^2+25b^2+15ab+12a-20b+16$ by $3a-5b-4$

Resolve into factors

6. $x^3-y^3-1-3xy$

7. $x^3-y^3+6xy+8$

8. $x^3-8y^3-27z^3-18xyz$

Find the value of

9. $x^3+y^3+18xy-216$, when $x+y=6$

10. $a^3-8b^3-24ab-64$, when $a-2b=4$

11. $(s-a)^3+(s-b)^3+(s-c)^3-3(s-a)(s-b)(s-c)$, when $3s=a+b+c$

12. Show that $(a-2b)^3+(2b-3c)^3+(3c-a)^3$
$$=3(a-2b)(2b-3c)(3c-a)$$

13. Show that $(x+y-2z)^3+(y+z-2x)^3+(z+x-2y)^3$
$$=3(x+y-2z)(y+z-2x)(z+x-2y)$$

14. Show that $(a+2b-3c)^3+(b+2c-3a)^3+(c+2a-3b)^3$
$$=3(a+2b-3c)(b+2c-3a)(c+2a-3b)$$

15. Show that $(2p-5q+3r)^3+(2q-5r+3p)^3+(2r-5p+3q)^3$
$$=3(2p-5q+3r)(2q-5r+3p)(2r-5p+3q)$$

16. Find the value of $x^6+y^6-z^6+3x^2y^2z^2$, when $x=a^2-b^2$, $y=2ab$, $z=a^2+b^2$

17. Find the value of $x^3+y^3+z^3-3xyz$, when $x=658$, $y=668$, $z=674$

129. Formula $(a-b)(a-c)(b-c)$
$$=a^2(b-c)+b^2(c-a)+c^2(a-b)$$
$$=bc(b-c)+ca(c-a)+ab(a-b).$$

$$[(a-b)(a-c)(b-c)=\{a^2-a(b+c)+bc\}(b-c)$$
$$=a^2(b-c)-a(b^2-c^2)+bc(b-c)$$
$$=a^2(b-c)+b^2(c-a)+c^2(a-b)\,]$$

Cor. 1. Conversely, $a^2(b-c)+b^2(c-a)+c^2(a-b)$
$$=(a-b)(a-c)(b-c)$$

Hence, we know at once the factors of an expression which is of the form $a^2(b-c)+b^2(c-a)+c^2(a-b)$

Cor. 2. Since $a-c=-(c-a)$, we have
$$(a-b)(a-c)(b-c)=-(a-b)(b-c)(c-a)$$

Hence, the above relation can also be put in the form
$$a^2(b-c)+b^2(c-a)+c^2(a-b)=-(a-b)(b-c)(c-a)$$

Cor. 3. Since $a^2(b-c)+b^2(c-a)+c^2(a-b)$ can be put in the form $ab(a-b)+bc(b-c)+ca(c-a)$, we have also
$$ab(a-b)+bc(b-c)+ca(c-a)=-(a-b)(b-c)(c-a)$$

Example. Simplify $(a+2b+3c)^2(a-2b+c)$
$$+(b+2c+3a)^2(b-2c+a)+(c+2a+3b)^2(c-2a+b)$$
$$+(a-2b+c)(b-2c+a)(c-2a+b)$$

Putting x for $a+2b+3c$, y for $b+2c+3a$, and z for $c+2a+3b$, we have
$$\left.\begin{aligned} y-z&=a-2b+c\\ z-x&=b-2c+a\\ x-y&=c-2a+b \end{aligned}\right\}$$

Hence, the given expression
$$=x^2(y-z)+y^2(z-x)+z^2(x-y)+(y-z)(z-x)(x-y)$$
$$=-(y-z)(z-x)(x-y)+(y-z)(z-x)(x-y)=0$$

EXERCISE 74.

1. Show that $(x-2y+z)(2x-y-z)(y-2z+x)$
$$=(x-y)^2(y-2z+x)+(y-z)^2(z-2x+y)+(z-x)^2(x-2y+z)$$

2. Show that $(a+b)^2(b-a)+(b+c)^2(c-b)+(c+a)^2(a-c)$
$$+(b-a)(c-b)(a-c)=0.$$

3. Resolve into factors
$$2(a-b+c)^2(a-c)+2(b-c+a)^2(b-a)+2(c-a+b)^2(c-b).$$

4. Resolve into factors
$$(x+y)^2(y-x)+(y+z)^2(z-y)+(z+x)^2(x-z)$$

5. Simplify $2(a-b-c)^2(b-c)+2(b-c-a)^2(c-a)$
$$+2(c-a-b)^2(a-b)+8(a-b)(b-c)(c-a)$$

6. Simplify $(x-y)(y-z)(x-2y+z)$
$+(y-z)(z-x)(y-2z+x)+(z-x)(x-y)(z-2x+y)$
$+(x-2y+z)(y-2z+x)(z-2x+y)$

130. Formula $(b+c)(c+a)(a+b)$

$$=a^2(b+c)+b^2(c+a)+c^2(a+b)+2abc$$
$$=a(b^2+c^2)+b(c^2+a^2)+c(a^2+b^2)+2abc$$
$$=bc(b+c)+ca(c+a)+ab(a+b)+2abc$$
$$=(a+b+c)(bc+ca+ab)-abc.$$

[$(b+c)(c+a)(a+b)$

$$=(b+c)\{(a+b)(a+c)\}=(b+c)\{a^2+a(b+c)+bc\}$$
$$=a^2(b+c)+a(b+c)^2+bc(b+c)$$
$$=a^2(b+c)+a(b^2+2bc+c^2)+b^2c+bc^2$$
$$=a^2(b+c)+b^2(c+a)+c^2(a+b)+2abc$$

[re-arranging the terms]

But, $a^2(b+c)+b^2(c+a)+c^2(a+b)$

$$=a(b^2+c^2)+b(c^2+a^2)+c(a^2+b^2)$$

[re-arranging the terms]

$$=(b^2c+bc^2)+(c^2a+ca^2)+(a^2b+ab^2)$$
$$=bc(b+c)+ca(c+a)+ab(a+b)$$
$$=bc(a+b+c-a)+ca(a+b+c-b)+ab(a+b+c-c)$$
$$=bc(a+b+c)+ca(a+b+c)+ab(a+b+c)$$
$$-bca \qquad -cab \qquad -abc$$
$$=(a+b+c)(ac+ca+ab)-3abc$$

Hence, the result follows]

131. Formula $(a+b+c)(bc+ca+ab)=P+3abc$, where P stands for any of the equivalent forms

(i) $a^2(b+c)+b^2(c+a)+c^2(a+b)$;

(ii) $bc(b+c)+ca(c+a)+ab(a+b)$;

(iii) $a(b^2+c^2)+b(c^2+a^2)+c(a^2+b^2)$.

[From Art 130, we have by transposition, or by direct multiplication $(a+b+c)(bc+ca+ab)$

$$=a^2(b+c)+b^2(c+a)+c^2(a+b)+3abc$$
$$=a(b^2+c^2)+b(c^2+a^2)+c(a^2+b^2)+3abc$$
$$=bc(b+c)+ca(c+a)+ab(a+b)+3abc$$]

Example 1. Find the product of

$$(2x+3y+5z)(15yz+10zx+6xy)$$

Putting a, b and c for $2x$, $3y$ and $5z$ respectively,

we have $\quad a+b+c=2x+3y+5z$

$$bc+ca+ab=15yz+10zx+6xy,$$

$$\begin{aligned}&(2x+3y+5z)(15yz+10zx+6xy)\\&=(a+b+c)(bc+ca+ab)\\&=a^2(b+c)+b^2(c+a)+c^2(a+b)+3abc\\&=4x^2(3y+5z)+9y^2(5z+2x)+25z^2(2x+3y)+3\,2x\,3y\,5z\\&=12x^2y+20x^2z+45y^2z+18y^2x+50z^2x+75z^2y+90xyz\end{aligned}$$

Example 2. Show that $(x+3y+12z)(12yz+4zx+xy)-12xyz$
$$=(y+4z)(12z+x)(x+3y)$$

Putting a b, and c for x, $3y$ and $12z$ respectively

we have $\quad a+b+c=x+3y+12z$

$$\begin{aligned}bc+ca+ab&=36yz+12zx+3xy\\&=3(12yz+4zx+xy)\\abc&=36xyz\end{aligned}$$

$\therefore$ the left-hand side $=\frac{1}{3}\{(a+b+c)(bc+ca+ab)-abc\}$

$=\frac{1}{3}(b+c)(c+a)(a+b)$ [Art 130]

$=\frac{1}{3}(3y+12z)(12z+x)(x+3y)$

[restoring values of a, b, c]

$=(y+4z)(12z+x)(x+3y)$

EXERCISE 75.

Write down the products of the following

1. $(x+2y)(2y+3z)(3z+x)$ **2.** $(8x+y)(y+5z)(5z+8x)$.

3. $(a+2b)(2b+3c)(3c+a)$

4. $(3x+y+10z)(10yz+30zx+3xy)$

5. $(x+2y+z)(2x+y+z)(x+y+2z)$

6. $(a-2b)(2b-3c)(3c+a)$

Simplify the following

7. $a(b+c-a)^2+b(c+a-b)^2+c(a+b-c)^2$
$$+(b+c-a)(c+a-b)(a+b-c).$$

8. $c(b+c-a)(c+a-b)+a(c+a-b)(a+b-c)$
$+b(a+b-c)(b+c-a)+(b+c-a)(c+a-b)(a+b-c)$

9. $(y+z)^2(2x+y+z)+(z+x)^2(x+2y+z)+(x+y)^2(x+y+2z)$
$-(2x+y+z)(x+2y+z)(x+y+2z)+2(y+z)(z+x)(x+y)$

10. $2a(b+c-a)^2+2b(c+a-b)^2+2c(a+b-c)^2-3abc$
$+2(a+b+c)\{(c+a-b)(a+b-c)+(a+b-c)(b+c-a)$
$+(b+c-a)(c+a-b)\}$

11. Prove that $(x+y-z)\{(y+z-x)^2+(z+x-y)^2\}+(y+z-x)$
$+\{(z+x-y)^2+(x+y-z)^2\}+(z+x-y)\{(x+y-z)^2+(y+z-x)^2\}$
$+2(y+z-x)(z+x-y)(x+y-z)=8xyz$

132. Formula

$$(a+b+c)^3=a^3+b^3+c^3+3(b+c)(c+a)(a+b).$$

$$[\ (a+b+c)^3=\{(a+b)+c\}^3$$
$$=(a+b)^3+c^3+3(a+b)c\{(a+b)+c\}, \quad \text{[Art 57]}$$
$$=\{a^3+b^3+3ab(a+b)\}+c^3+3(a+b)c(a+b+c)$$
$$=a^3+b^3+c^3+\{3ab(a+b)+3(a+b)c(a+b+c)\}$$
$$=a^3+b^3+c^3+3(a+b)\{ab+c(a+b+c)\}$$
$$=a^3+b^3+c^3+3(a+b)\{c^2+c(a+b)+ab\}$$
$$=a^3+b^3+c^3+3(a+b)(c+b)(c+a) \quad \text{[Art 61]}$$
$$=a^3+b^3+c^3+3(b+c)(c+a)(a+b)\ ]$$

Cor. $(a+b+c)^3-a^3-b^3-c^3=3(b+c)(c+a)(a+b)$

Example 1. Factorise $8(x+y+z)^3-(y+z)^3-(z+x)^3-(x+y)^3$

Put a, b and c for $y+z$, $z+x$ and $x+y$ respectively

We have $\quad a+b+c=2(x+y+z)$

The given expression

$$=\{2(x+y+z)\}^3-(y+z)^3-(z+x)^3-(x+y)^3$$
$$=(a+b+c)^3-a^3-b^3-c^3$$
$$=3(b+c)(c+a)(a+b) \quad \text{[Cor.]}$$
$$=3(2x+y+z)(x+2y+z)(x+y+2z)$$

[restoring the values of a, b, c]

Example 2. Show that

$$(x+y+z)^3=(y+z-x)^3+(z+x-y)^3+(x+y-z)^3+24xyz$$

Put a b, c for $y+z-x$, $z+x-y$ and $x+y-z$ respectively

We have $a+b+c=(y+z-x)+(z+x-y)+(x+y-z)=x+y+z$

$$b+c=(z+x-y)+(x+y-z)=2x$$

$$c+a=(x+y-z)+(y+z-x)=2y$$

$$a+b=(y+z-x)+(z+x-y)=2z$$

$$\begin{aligned}(x+y+z)^3&=(a+b+c)^3=a^3+b^3+c^3+3(b+c)(c+a)(a+b)\\&=(y+z-x)^3+(z+x-y)^3+(x+y-z)^3\\&\qquad+3\,2x\,2y\,2z\\&=(y+z-x)^3+(z+x-y)^3+(x+y-z)^3+24xyz\end{aligned}$$

EXERCISE 76.

1. If $a+b+c=0$, show that $a^3+b^3+c^3=3a(c+a)(a+b)$
$=3b(b+c)(b+a)=3c(c+a)(c+b)=3abc$

2. If $2s=x+y+z$, prove that
$$(s-x)^3+(s-y)^3+(s-z)^3+3xyz=s^3$$

3. Prove that $(2x-y-z)^3+(2y-z-x)^3+(2z-x-y)^3$
$=3(2x-y-z)(2y-z-x)(2z-x-y)$

4. Simplify $(3x-y-z)^3+(3y-z-x)^3+(3z-x-y)^3$
$+24(y+z-x)(z+x-y)(x+y-z)-x^3-y^3-z^3$
$-3(y+z)(z+x)(x+y)$

5. Show that $(2x-y-z)^3+y^3+z^3+3(y+z)(2x-y)(2x-z)$
$=(2x-y-3z)^3+y^3+27z^3+3(y+3z)(2x-y)(2x-3z)$

6. If $2s=x+y+z$, prove that
$$s^3+(s-2x)^3+(s-2y)^3+(s-2z)^3-24(s-x)(s-y)(s-z)=0$$

7. If $3s=2(x+y+z)$, show that $(s-y-z)^3+(s-z-x)^3$
$+(s-x-y)^3+3(y+z-s)(z+x-s)(x+y-s)=0$

8. Simplify
$$(b+c-a)^3+(c+a-b)^3+(a+b-c)^3-(a+b+c)^3+108abc$$

9. Simplify
$$(x+y+z)^3-(y+z)^3-(z+x)^3-(x+y)^3+x^3+y^3+z^3$$

10. Factorise $x^3-(2x-y-z)^3-(2y-z-x)^3+(y-2z)^3$

11. Resolve into factors
$$64(x+y+z)^3-(2x+y+z)^3-(x+2y+z)^3-(x+y+2z)^3.$$

Find the value of

12. $a^3+b^3+c^3$, when $b+c=10$, $c+a=16$, $a+b=20$

13. $x^3+y^3+z^3$, when $x=32$, $y=-25$ and $z=-7$

14. $(x+y+z)^3-(x+z-y)^3-(y+z-x)^3-(x+y-z)^3-23xyz$
when $x=10$, $y=64$ and $z=2$

15. $(6x-y-z)^3+y^3+z^3+3(y+z)(6x-y)(6x-z)$,
when $x=\frac{11}{6}$, $y=\frac{115}{113}$ and $z=17$.

133. Recapitulation of the Formulæ.

The different formulæ treated of in Chapter IV as well as in the present one are grouped below to facilitate any reference to them It is desired, however, that the student should commit them so fully to memory that the necessity even for occasional references may be altogether done away with

I $(a+b)^2=a^2+2ab+b^2$

II $(a-b)^2=a^2-2ab+b^2$

III $(a+b)(a-b)=a^2-b^2$

IV $\left.\begin{aligned}(a+b)^3&=a^3+3a^2b+3ab^2+b^3\\&=a^3+b^3+3ab(a+b)\end{aligned}\right\}$

V $\left.\begin{aligned}(a-b)^3&=a^3-3a^2b+3ab^2-b^3\\&=a^3-b^3-3ab(a-b)\end{aligned}\right\}$

VI $\left.\begin{aligned}a^3+b^3&=(a+b)^3-3ab(a+b)\\&=(a+b)(a^2-ab+b^2)\end{aligned}\right\}$

VII $\left.\begin{aligned}a^3-b^3&=(a-b)^3+3ab(a-b)\\&=(a-b)(a^2+ab+b^2)\end{aligned}\right\}$

VIII $(x+a)(x+b)=x^2+(a+b)x+ab$

IX $(x-a)(x+b)=x^2+(b-a)x-ab$

X $(x-a)(x-b)=x^2-(a+b)x+ab$

XI $(x+a)(x+b)(x+c)$
$=x^3+(a+b+c)x^2+(bc+ca+ab)x+abc$

XII $(x-a)(x-b)(x-c)$
$=x^3-(a+b+c)x^2+(bc+ca+ab)x-abc$

XIII $\left.\begin{aligned}a^3+b^3+c^3-3abc&=(a+b+c)(a^2+b^2+c^2-bc-ca-ab)\\&=\tfrac{1}{2}(a+b+c)\{(b-c)^2+(c-a)^2+(a-b)^2\}\end{aligned}\right\}$

XIV $\left.\begin{aligned}(a-b)(a-c)(b-c)&=-(b-c)(c-a)(a-b)\\&=a^2(b-c)+b^2(c-a)+c^2(a-b)\\&=bc(b-c)+ca(c-a)+ab(a-b)\\&=-\{a(b^2-c^2)+b(c^2-a^2)+c(a^2-b^2)\}\end{aligned}\right\}$

XV $(b+c)(c+a)(a+b)$
$$=a^2(b+c)+b^2(c+a)+c^2(a+b)+2abc$$
$$=a(b^2+c^2)+b(c^2+a^2)+c(a^2+b^2)+2abc$$
$$=bc(b+c)+ca(c+a)+ab(a+b)+2abc$$
$$=(a+b+c)(bc+ca+ab)-abc$$

XVI $(a+b+c)(bc+ca+ab)$
$$=(b+c)(c+a)(a+b)+abc$$
$$=a^2(b+c)+b^2(c+a)+c^2(a+b)+3abc$$
$$=bc(b+c)+ca(c+a)+ab(a+b)+3abc$$
$$=a(b^2+c^2)+b(c^2+a^2)+c(a^2+b^2)+3abc$$

XVII $(a+b+c)^3=a^3+b^3+c^3+3(b+a)(c+a)(a+b)$
$$=a^3+b^3+c^3+3\{a^2(b+c)+b^2(c+a)+c^2(a+b)\}+6abc$$
or, $(a+b+c)^3-a^3-b^3-c^3=3(b+c)(c+a)(a+b)$

The following useful results are deserving of notice They can be deduced from the above formulæ or verified by actual multiplication

XVIII $(a+b)^2+(a-b)^2=2(a^2+b^2)$

XIX $(a+b)^2-(a-b)^2=4ab$

or, $ab=\left(\frac{a+b}{2}\right)^2-\left(\frac{a-b}{2}\right)^2.$

XX $(a+b+c)^2=a^2+b^2+c^2+2bc+2ca+2ab$

XXI $(bc+ca+ab)^2=b^2c^2+c^2a^2+a^2b^2+2abc(a+b+c)$

XXII $(b-c)+(c-a)+(a-b)=0$

XXIII $a(b-c)+b(c-a)+c(a-b)=0$

XXIV $\frac{1}{2}\{(b-c)^2+(c-a)^2+(a-b)^2\}=a^2+b^2+c^2-bc-ca-ab$

XXV $(a+b)^3+(a-b)^3=2a^3+6ab^2$

XXVI $(a+b)^3-(a-b)^3=6a^2b+2b^3$

XXVII. $(a^2+ab+b^2)(a^2-ab+b^2)=a^4+a^2b^2+b^4$

XXVIII $(a+b+c)(b+c-a)(c+a-b)(a+b-c)$
$$=2b^2c^2+2c^2a^2+2a^2b^2-a^4-b^4-c^4$$

XXIX $(a+b)^4=a^4+4a^3b+6a^2b^2+4ab^3+b^4$

XXX $(a+b)^5=a^5+5a^4b+10a^3b^2+10a^2b^3+5ab^4+b^5$

CHAPTER XXII

HARDER FACTORS AND IDENTITIES

I. Factors.

We have already explained in Chapter XII how simple expressions of the types a^2-b^2 a^3+b^3, a^3-b^3 and ax^2+bx+c can be resolved into factors, and shall in this section consider factorisations of a harder type

134. To factorise expressions of the form $a^3+b^3+c^3-3abc$.

Since, $\quad b^3+c^3=(b+c)^3-3bc(b+c)$,

we have $a^3+b^3+c^3-3abc$

$$\begin{aligned}
&=a^3+\{(b+c)^3-3bc(b+c)\}-3abc\\
&=\{a^3+(b+c)^3\}-3bc\{(b+c)+a\}\\
&=\{a+(b+c)\}\{a^2-a(b+c)+(b+c)^2\}-3bc(a+b+c)\\
&=(a+b+c)\{a^2-ab-ac+b^2+2bc+c^2-3bc\}\\
&=(a+b+c)(a^2+b^2+c^2-bc-ca-ab)\\
&=\tfrac{1}{2}(a+b+c)\{(b-c)^2+(c-a)^2+(a-b)^2\}
\end{aligned}$$

Example 1. Factorise $a^3-b^3+c^3+3abc$

The expression

$$\begin{aligned}
&=a^3+(-b)^3+c^3-3a(-b)c\\
&=\{a+(-b)+c\}\{a^2+(-b)^2+c^2-(-b)c-ca-a(-b)\}\\
&=(a-b+c)(a^2+b^2+c^2+bc-ca+ab)
\end{aligned}$$

Example 2. Factorise $x^3-y^3+6xy+8$.

The given expression

$$\begin{aligned}
&=x^3+(-y)^3+(2)^3-3x(-y)\,2\\
&=\{x+(-y)+2\}\{x^2+(-y)^2+2^2-(-y)\,2-2x-x(-y)\}\\
&=(x-y+2)(x^2+y^2+4+2y-2x+xy)
\end{aligned}$$

Example 3. Resolve into factors x^6+32x^3-64

The given expression

$$=x^6+8x^3-64+24x^3$$
$$=(x^2)^3+(2x)^3+(-4)^3-3\,x^2\,2x\,(-4)$$
$$=\{x^2+2x+(-4)\}\{(x^2)^2+(2x)^2+(-4)^2-2x(-4)$$
$$-(-4)x^2-x^2\,2x\}$$
$$=(x^2+2x-4)(x^4+4x^2+16+8x+4x^2-2x^3)$$
$$=(x^2+2x-4)(x^4-2x^3+8x^2+8x+16)$$

Example 4. Find the quotient of $a^3+b^3+1-3ab$ by $a+b+1$

Since, $a^3+b^3+1-3ab=a^3+b^3+1^3-3ab.1$

$$=(a+b+1)\{a^2+b^2+1^2-b\,1-1\,a-ab\}$$
$$=(a+b+1)(a^2+b^2+1-b-a-ab),$$

the reqd quotient$=a^2+b^2+1-b-a-ab$

EXERCISE 77.

Factorise

1. $x^3+y^3-z^3+3xyz$
2. $p^3-8q^3-r^3-6pqr$.
3. $8x^3-27y^3-z^3-18xyz$
4. $a^3+8b^3+1-6ab$.
5. $8a^3+27b^3-64+72ab$
6. Find the quotient of $x^3-y^3+6xy+8$ by $x-y+2$
7. Factorise x^6+5x^3+8
8. Resolve into factors
$$(x-y)^3-(y-z)^3+(z-x)^3+3(y-z)(z-x)(x-y)$$
9. Factorise a^6-18a^3+125

Find the quotient of

10. $x^3+27-5y(25y^2-9x)$ by $x^2+25y^2+9+5xy-3x+15y$.
11. $a^3+b^3-c^3+3abc$ by $a+b-c$
12. $x^3-y^3-1-3xy$ by $x-y-1$
13. $x^3-8y^3+27z^3+18xyz$ by $x-2y+3z$
14. $8a^3-27b^3-c^3-18abc$ by $4a^2+9b^2+c^2+6ab+2ac-3bc$
15. Factorise $14a^3-4b^3+9a^2b$

135. To factorise expressions of the form

$$(a+b+c)(bc+ca+ab)-abc.$$

The expression $=\{a+(b+c)\}\{a(b+c)+bc\}-abc$

$$=a^2(b+c)+a(b+c)^2+bc(b+c)$$
$$=(b+c)\{a^2+a(b+c)+bc\}$$
$$=(b+c)(a+b)(a+c)=(b+c)(c+a)(a+b).$$

Cor. 1. $(a+b+c)(bc+ca+ab)-(b+c)(c+a)(a+b)=abc$

Cor. 2. $(b+c)(c+a)(a+b)+abc=(a+b+c)(bc+ca+ab)$

136. To factorise expressions of the form

(i) $P+2abc$;

and (ii) $P+3abc$,

where P stands for any of the equivalent forms

(1) $a^2(b+c)+b^2(c+a)+c^2(a+b)$

(2) $bc(b+c)+ca(c+a)+ab(a+b)$.

(3) $a(b^2+c^2)+b(c^2+a^2)+c(a^2+b^2)$.

(i) Taking the 1st value of P, we have

$$P+2abc=a^2(b+c)+b^2(c+a)+c^2(a+b)+2abc$$
$$=a^2(b+c)+a(b^2+2bc+c^2)+b^2c+bc^2$$

[arranging in powers of a].

$$=a^2(b+c)+a(b+c)^2+bc(b+c)$$
$$=(b+c)\{a^2+a(b+c)+bc\}$$
$$=(b+c)(a+b)(a+c)=(b+c)(c+a)(a+b)$$

(ii) Taking the 2nd value of P, we have

$$P+3abc=bc(b+c)+ca(c+a)+ab(a+b)+3abc$$
$$=bc(b+c)+ca(c+a)+ab(a+b)+abc+abc+abc$$
$$=\{bc(b+c)+abc\}+\{ca(c+a)+abc\}+\{ab(a+b)+abc\}$$
$$=bc(a+b+c)+ca(c+a+b)+ab(a+b+c)$$
$$=(a+b+c)(bc+ca+ab)$$

137. To factorise expressions of the type Q.

where Q stands for any of the equivalent forms

(1) $a^2(b-c)+b^2(c-a)+c^2(a-b)$.

(2) $bc(b-c)+ca(c-a)+ab(a-b)$.

(3) $-\{a(b^2-c^2)+b(c^2-a^2)+c(a^2-b^2)\}$.

From the first form of Q, we have

$$\begin{aligned} &a^2(b-c)+b^2(c-a)+c^2(a-b) \\ &\quad =a^2(b-c)-a(b^2-c^2)+b^2c-bc^2 \\ &\qquad\qquad\text{[arranging in powers of } a\text{]} \\ &\quad =a^2(b-c)-a(b^2-c^2)+bc(b-c) \\ &\quad =(b-c)\{a^2-a(b+c)+bc\} \\ &\quad =(b-c)(a-b)(a-c)=-(b-c)(c-a)(a-b) \end{aligned}$$

Cor. Putting, a^2, b^2 and c^2 for a, b and c respectively in the above, we have

$$\begin{aligned} &a^4(b^2-c^2)+b^4(c^2-a^2)+c^4(a^2-b^2) \\ &\quad =-(b^2-c^2)(c^2-a^2)(a^2-b^2) \\ &\quad =-(b-c)(c-a)(a-b)(b+c)(c+a)(a+b) \end{aligned}$$

Example. Factorise

$$(x-a)^2(b-c)+(x-b)^2(c-a)+(x-c)^2(a-b)$$

The expression $=(x^2-2ax+a^2)(b-c)+(x^2-2bx+b^2)(c-a)$

$$\begin{aligned} &\qquad +(x^2-2cx+c^2)(a-b) \\ &=x^2\{(b-c)+(c-a)+(a-b)\}-2x\{a(b-c) \\ &\qquad +b(c-a)+c(a-b)\} \\ &\qquad +\{a^2(b-c)+b^2(c-a)+c^2(a-b)\} \\ &\qquad\qquad\text{[arranged in powers of } x\text{]} \\ &=x^2\,0-2x\,0-(b-c)(c-a)(a-b) \\ &=-(b-c)(c-a)(a-b) \end{aligned}$$

138. To factorise $a^3(b-c)+b^3(c-a)+c^3(a-b)$.

$$\begin{aligned} &a^3(b-c)+b^3(c-a)+c^3(a-b) \\ &\quad =a^3(b-c)-a(b^3-c^3)+bc(b^2-c^2) \\ &\qquad\qquad\text{[arranging in powers of } a\text{]} \\ &\quad =(b-c)\{a^3-a(b^2+bc+c^2)+bc(b+c)\} \\ &\quad =(b-c)\{-b^2(a-c)-bc(a-c)+a(a^2-c^2)\} \\ &\qquad\qquad\text{[arranging in powers of } b\text{]} \end{aligned}$$

$$=(b-c)(a-c)\{-b^2-bc+a(a+c)\}$$

$$=(b-c)(a-c)\{c(a-b)+a^2-b^2\}$$ [arranging the last factors in powers of c]

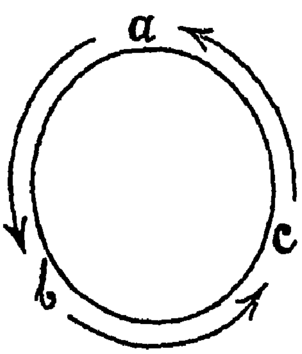
$$=(b-c)(a-c)(a-b)(c+b+a)$$

$$=-(b-c)(c-a)(a-b)(a+b+c)$$

Note *It must be observed that (i) as soon as the given expression is arranged according to powers of a, one of the factors, namely, $b-c$, becomes obvious, (ii) when the expression within larger brackets is arranged according to powers of b, the next factor, $a-c$, becomes obvious, (iii) when the expression now within larger brackets is arranged according to powers of c, the third factor, $a-b$ becomes obvious*

139. Cyclic Order. There is a certain peculiarity in the arrangement of three letters a, b, c in the different expressions of Arts 137 and 138 Thus, in any of the equivalent forms of Q in Art 137, we get the second term by changing a, b, c of the first into b, c, a respectively the third term by changing b, c, a of the second into c, a, b respectively; and the first term by changing c, a, b of the third into a, b, c respectively The orders in which the letters a, b, c are to be changed successively will be best understood in the following way

Let the letters a, b, c be arranged round the circumference of a circle as shown in the diagram, starting from the letter a and moving in the direction of the arrow-head we notice that the order of the letters is abc Similarly starting from b and c successively and moving in the same direction, we notice that the orders of the letters are bca and cab respectively



The letters a, b, c when arranged in this manner, are said to be in *cyclic order*

Thus, a, b, c are arranged in cyclic order in the following:

(i) $b+c, c+a$ and $a+b$; (ii) $b-c, c-a$ and $a-b$,

(iii) $b+c-a, c+a-b$ and $a+b-c$,

(iv) bc, ca and ab;

(v) $a^2(b-c), b^2(c-a)$ and $c^2(a-b)$

and so on

140. To factorise $a^3(b^2-c^2)+b^3(c^2-a^2)+c^3(a^2-b^2)$.

In this expression also the letters occur in *cyclic order* and we can at once proceed as in the last example

$$\begin{aligned} a^3(b^2-c^2)+b^3(c^2-a^2)+c^3(a^2-b^2) \\ &= a^3(b^2-c^2)-a^2(b^3-c^3)+b^2c^2(b-c) \\ &\qquad \text{[arranged according to powers of } a\text{]} \\ &= (b-c)\{a^3(b+c)-a^2(b^2+bc+c^2)+b^2c^2\} \\ &= (b-c)\{-b^2(a^2-c^2)+ba^2(a-c)+a^2c(a-c)\} \\ &\qquad \text{[arranged according to powers of } b\text{]} \\ &= (b-c)(a-c)\{-b^2(a+c)+ba^2+a^2c\} \\ &= (b-c)(a-c)\{c(a^2-b^2)+ab(a-b)\} \\ &\qquad \text{[arranged according to powers of } c\text{]} \\ &= (b-c)(a-c)(a-b)\{c(a+b)+ab\} \\ &= -(b-c)(c-a)(a-b)(bc+ca+ab) \end{aligned}$$

141. To factorise $(a+b+c)^3-a^3-b^3-c^3$

[See Art 132, Cor]

142. To factorise $2b^2c^2+2c^2a^2+2a^2b^2-a^4-b^4-c^4$.

The given expression

$$\begin{aligned} &= 4b^2c^2-(a^4+b^4+c^4+2b^2c^2-2c^2a^2-2a^2b^2) \\ &= (2bc)^2-(a^2-b^2-c^2)^2 \\ &= \{2bc+(a^2-b^2-c^2)\}\{2bc-(a^2-b^2-c^2)\} \\ &= \{a^2-(b^2-2bc+c^2)\}\{(b^2+2bc+c^2)-a^2\} \\ &= \{a^2-(b-c)^2\}\{(b+c)^2-a^2\} \\ &= \{a+(b-c)\}\{a-(b-c)\}\{(b+c)+a\}\{(b+c)-a\} \\ &= (a+b-c)(a-b+c)(b+c+a)(b+c-a) \\ &= (a+b+c)(b+c-a)(c+a-b)(a+b-c) \end{aligned}$$

EXERCISE 78.

Resolve into factors

1. $a^4(b-c)+b^4(c-a)+c^4(a-b)$.

2. $b^2c^2(b^2-c^2)+c^2a^2(c^2-a^2)+a^2b^2(a^2-b^2)$

3. $a^5(b-c)+b^5(c-a)+c^5(a-b)$

4. $bc(b^3-c^3)+ca(c^3-a^3)+ab(a^3-b^3)$

5. $b^2c^2(b-c)+c^2a^2(c-a)+a^2b^2(a-b)$

6. $x(y-z)^2+y(z-x)^2+z(x-y)^2+8xyz$

7. $x^2(y-z)^3+y^2(z-x)^3+z^2(x-y)^3$

8. $(y-z)^5+(z-x)^5+(x-y)^5$

9. $(x^2+2x+4)(y-z)+(y^2+2y+4)(z-x)+(z^2+2z+4)(x-y)$

10. $\{x^2-(b+c)x+bc\}(b-c)+\{x^2-(c+a)x+ca\}(c-a)$
$+\{x^2-(a+b)x+ab\}(a-b)$

11. $(x+b)(x+c)(b-c)+(x+c)(x+a)(c-a)$
$+(x+a)(x+b)(a-b)$

12. $a(b+c)^2+b(c+a)^2+c(a+b)^2-3abc$

13. $8x^3-(y-z)^3-(z+x)^3-(x-y)^3$

14. $a^6(b^3-c^3)+b^6(c^3-a^3)+c^6(a^3-b^3)$

15. $x^6(y^4-z^4)+y^6(z^4-x^4)+z^6(x^4-y^4)$

16. $8(a+b+c)^3-(b+c)^3-(c+a)^3-(a+b)^3$

17. $yz(y+z)+zx(z+x)+xy(x+y)-x^3-y^3-z^3-2xyz$

18. $(x+1)^2(y-z)+(y+1)^2(z-x)+(z+1)^2(x-y)$

19. $(x+1)^3(y-z)+(y+1)^3(z-x)+(x+1)^3(x-y)$

20. $x(y-z)^3+y(z-x)^3+z(x-y)^3$

21. $2b^2c^2y^2z^2+2c^2a^2z^2x^2+2a^2b^2x^2y^2-a^4x^4-b^4y^4-c^4z^4$

22. $72y^2z^2+18z^2x^2+8x^2y^2-x^4-16y^4-81z^4$

23. Find the value of $2b^2c^2+2c^2a^2+2a^2b^2-a^4-b^4-c^4$,
when $b+c-a=7$, $c+a-b=10$ and $a+b-c=3$

24. Evaluate $a^2(b+c)+b^2(c+a)+c^2(a+b)$,
when $a+b+c=20$, $bc+ca+ab=18$ and $abc=37$

25. Evaluate $(a+b+c)^3-a^3-b^3-c^3+3abc$
when $a+b+c=13$ and $a^2+b^2+c^2=69$

143. Factors of Reciprocal Expressions.

Definition. An algebraical expression in which co-efficients of the terms equidistant from the beginning and end are same, is called a **reciprocal** or **recurring** expression

Thus, $x^4+4x^3+5x^2+4x+1$ is a reciprocal expression

Example 1. Resolve into factors $x^4+2x^3+3x^2+2x+1$

The expression $=(x^4+1)+(2x^3+2x)+3x^2$, [collecting terms with equal co-efficients]

$$=\{(x^2+1)^2-2x^2\}+2x(x^2+1)+3x^2$$
$$=(x^2+1)^2+2x(x^2+1)+3x^2-2x^2$$
$$=(x^2+1)^2+2(x^2+1)\,x+x^2$$
$$=\{(x^2+1)+x\}^2$$
$$=(x^2+x+1)^2$$

Example 2. Factorise $a^4-5a^3-12a^2-5a+1$

The expression $=(a^4+1)^2-(5a^3+5a)-12a^2$, [collecting terms with equal co-efficients]

$$=\{(a^2+1)^2-2a^2\}-5a(a^2+1)-12a^2$$
$$=(a^2+1)^2-5(a^2+1)\,a-2a^2-12a^2$$
$$=x^2-5xa-14a^2 \qquad \text{[putting } x \text{ for } a^2+1\text{]}$$
$$=(x+2a)(x-7a)$$
$$=(a^2+1+2a)(a^2+1-7a), \qquad \text{[restoring the value of } x\text{]}$$
$$=(a+1)^2(a^2-7a+1)$$

144. Factors by trial.

Example 1. Resolve into factors x^3-2x^2-5x+6

On inspection we find that the given expression can be split up into parts each of which is divisible by $x-1$

Thus, the exp $=x^3-x^2-x^2+x-6x+6$

$$=(x^3-x^2)-(x^2-x)-(6x-6)$$
$$=x^2(x-1)-x(x-1)-6(x-1)$$
$$=(x-1)(x^2-x-6)$$
$$=(x-1)(x+2)(x-3)$$

Note *It is important for the student to observe that the given expression vanishes when 1, -2 or 3 is substituted for x Thus, it may be remembered as a general rule that* ***if any expression involving x vanishes when $x=a$, $x-a$ is a factor of that expression.***

The above general rule leads to the following particular cases

(1) If in any expression containing integral powers of x the sum of the co-efficients is zero, $x-1$ is a factor of that expression

(2) If in any expression containing integral powers of x, the sum of the co-efficients of odd powers of x is equal to the sum of the remaining co-efficients, $x+1$ is a factor of that expression

Thus in example 1 above the sum of the co-efficients of the expression $=1+(-2)+(-5)+6=1-2-5+6=0$

Hence, $x-1$ is a factor of the expression

Again, in the expression x^3+3x^2+3x+1, the odd powers of x are x^3 and x

The sum of their co-efficients $=1+3=4$ and the sum of the remaining co-efficients $=3+1=4$

These two sums being equal, the expression x^3+3x^2+3x+1 must have $(x+1)$ as factor

Example 2. Resolve into factors $x^3+6x^2+11x+6$

The sum of the co-efficients of odd powers of $x=1+11=12$ and the sum of the remaining co-efficients $=6+6=12$

These two sums being equal, $x+1$ must be a factor of the given expression Now, grouping the terms into parts each of which is divisible by $x+1$, we have

$$\begin{aligned}\text{the expression} &= x^3+x^2+5x^2+5x+6x+6\\ &=(x^3+x^2)+(5x^2+5x)+(6x+6)\\ &=x^2(x+1)+5x(x+1)+6(x+1)\\ &=(x+1)(x^2+5x+6)=(x+1)(x+2)(x+3)\end{aligned}$$

Example 3. Resolve into factors $8x^3+16x-9$

Putting y for $2x$, the given expression

$$\begin{aligned}&=(2x)^3+8\,2x-9\\ &=y^3+8y-9\end{aligned}$$

Now, the sum of the co-efficients of y^3+8y-9
$$=1+8-9=0$$

Hence, $y-1$ is a factor of this expression Next, arranging it into parts such that each part is divisible by $y-1$, we have $y^3+8y-9=y^3-y+9y-9$

$$\begin{aligned}&=y(y^2-1)+9(y-1)\\ &=(y-1)\{y(y+1)+9\}=(y-1)(y^2+y+9)\\ &=(2x-1)(4x^2+2x+9),\end{aligned}$$

[restoring the value of y]

Example 4. Resolve into factors

$$x^5+4x^4-13x^3-13x^2+4x+1$$

We notice that the sum of the co-efficients of odd powers of x

$$=1+(-13)+4=-8$$

and the sum of the remaining ce-efficients

$$=4+(-13)+1=-8$$

These two sums being equal $x+1$ must be a factor

Now, grouping the terms into parts each of which is divisible by $x+1$, we have the given expression

$$=(x^5+x^4)+(3x^4+3x^3)-(16x^3+16x^2)+(3x^2+3x)+(x+1)$$
$$=x^4(x+1)+3x^3(x+1)-16x^2(x+1)+3x(x+1)+(x+1)$$
$$=(x+1)(x^4+3x^3-16x^2+3x+1)$$

The factor $x^4+3x^3-16x^2+3x+1$ is a reciprocal expression Hence, proceeding as in Art 143,

we have, $x^4+3x^3-16x^2+3x+1$

$$=(x^4+1)+(3x^3+3x)-16x^2,$$

[grouping terms with equal co-efficients]

$$=\{(x^2+1)^2-2x^2\}+3x(x^2+1)-16x^2$$
$$=(x^2+1)^2+3(x^2+1)x-2x^2-16x^2$$
$$=y^2+3yx-18x^2, \qquad \text{[putting } y \text{ for } x^2+1\text{]}$$
$$=(y-3x)(y+6x)$$
$$=(x^2+1-3x)(x^2+1+6x), \text{[restoring the value of } y\text{]}$$
$$=(x^2-3x+1)(x^2+6x+1)$$

Hence, the given expression $=(x+1)(x^2-3x+1)(x^2+6x+1)$

Example 5. Resolve into factors $x^3+x^2-21x-38$

By trial we find that the given expression vanishes when $x=-2$

Hence, $x-(-2)=x+2$ is a factor Thus, we have

$$x^3+x^2-21x-38=(x^3+2x^2)-(x^2+2x)-(19x+38)$$

[splitting into parts divisible by $x+2$]

$$=x^2(x+2)-x(x+2)-19(x+2)$$
$$=(x+2)(x^2-x-19)$$

145. Factors of Homogeneous expressions of two dimensions.

The following examples will illustrate the process:

Example 1. Resolve into factors

$$6a^2+7ab+2b^2+11ac+7bc+3c^2.$$

If $a=0$, the expression becomes $2b^2+7bc+3c^2$,

$$\text{which}=(2b+c)(b+3c) \qquad (1)$$

If $b=0$, the expression reduces to $6a^2+11ac+3c^2$,

$$\text{which}=(3a+c)(2a+3c) \qquad (2)$$

If $c=0$, the expression reduces to $6a^2+7ab+2b^2$,

$$\text{which}=(3a+2b)(2a+b) \qquad (3)$$

Now comparing the results (1), (2) and (3), we notice that the given expression must be $=(3a+2b+c)(2a+b+3c)$, [since it is these factors which reduce to the form (1) when $a=0$ to the form (2) when $b=0$, and to the form (3) when $c=0$]

Alternative Method: Arranging the terms in descending powers of any one of the letters, say a, we have the given expression

$$=6a^2+(7b+11c)a+(2b^2+7bc+3c^2)$$
$$=6a^2+(7b+11c)a+(2b+c)(b+3c)$$

Now, split the product of (the co-efficient of a^2) and (the term independent of a) into two factors whose sum = the co-efficient of a

Thus split $6\times(2b+c)(b+3c)$ into two factors whose sum $=7b+11c$

By trial, the factors are $2(2b+c)$ and $3(b+3c)$

Hence the given expression

$$=6a^2+2(2b+c)a+3(b+3c)a+(2b+c)(b+3c)$$
$$=2a\{3a+(2b+c)\}+(b+3c)\{3a+(2b+c)\}$$
$$=(3a+2b+c)(2a+b+3c)$$

Example 2. Factorise $x^2-3xy+2y^2-2yz-4z^2$

The given expression is homogeneous in x, y and z

If $x=0$ the given expression reduces to $2y^2-2yz-4z^2$,

$$\text{which}=2(y^2-yz-2z^2)$$
$$=2(y+z)(y-2z)$$
$$=(2y+2z)(y-2z) \qquad (1)$$

If $y=0$, the given expression reduces to x^2-4z^2,

$$\text{which}=(-x+2z)(-x-2z). \qquad (2)$$

If $z=0$, the given expression reduces to $x^2-3xy+2y^2$,

$$\text{which}=(-x+2y)(-x+y) \qquad (3)$$

Now, comparing the results (1), (2) and (3), the given expression is evidently equal to

$$(-x+2y+2z)(-x+y-2z)$$
$$=(x-2y-2z)(x-y+2z)$$

Alternative Method: Arranging the expression in descending powers of any one of the letters, say x, we have the expression

$$=x^2-3yx+(2y^2-2yz-4z^2)$$
$$=x^2-3yx+2(y+z)(y-2z)$$

Next, splitting (co-efficient of x^2) $\times$ (term independent of x) i e, $2(y+z)(y-2z)$ into two factors whose sum

$$=\text{the co-efficient of } x, \text{ i e}, -3y,$$

we notice by trial that these factors are

$$-2(y+z) \text{ and } -(y-2z)$$

Hence, the given expression

$$=x^2-2(y+z)x-(y-2z)x+2(y+z)(y-2z)$$
$$=x\{x-2(y+z)\}-(y-2z)\{x-2(y+z)\}$$
$$=(x-2y-2z)(x-y+2z)$$

146. Factors of general expressions of the second degree in two or more letters.

Example. Factorise $6a^2+7ab+2b^2+11a+7b+3$

Arranging the expression in descending powers of any one of the letters, say a,

$$\text{the given expression}=6a^2+(7b+11)a+(2b^2+7b+3)$$
$$=6a^2+(7b+11)a+(2b+1)(b+3)$$

Now split the product of (the co-efficient of a^2) and (the term independent of a) i e, $6\times(2b+1)(b+3)$ into two factors whose sum = the co-efficient of a, i e, $7b+11$

The factors are evidently $2(2b+1)$ and $3(b+3)$

Hence the expression

$$=6a^2+2(2b+1)a+3(b+3)a+(2b+1)(b+3)$$
$$=2a\{3a+(2b+1)\}+(b+3)\{3a+(2b+1)\}$$
$$=(3a+2b+1)(2a+b+3).$$

147. Factors found by suitable arrangement and grouping of terms.

There are some expressions of which the factors become obvious after re-arrangement of the terms in a certain way, but there are others again which do not exactly come under this category. Hence no definite method can be specified as applicable to all cases that may be practically included in this article. We must, therefore content ourselves only with directing the student's attention to a few important cases more or less isolated, which will fairly introduce him to the subject under consideration.

Example 1. Resolve into factors $(3x^2-4b^2)a+(3a^2-4x^2)b$.

The given expression $=3x^2a-4b^2a+3a^2b-4x^2b$

$$=(3x^2a+3a^2b)-(4b^2a+4x^2b)$$

[taking the 3rd term with the 1st, and the 4th with the 2nd.]

$$=3a(x^2+ab)-4b(ab+x^2)$$
$$=(x^2+ab)(3a-4b).$$

Example 2. Resolve into factors $x^4+x^2y^2-y^2z^2-z^4$.

Combining the 4th term with the 1st, and the second with the 3rd, we have

$$x^4+x^2y^2-y^2z^2-z^4=(x^4-z^4)+(x^2y^2-y^2z^2)$$
$$=(x^2+z^2)(x^2-z^2)+y^2(x^2-z^2)$$
$$=(x^2-z^2)\{(x^2+z^2)+y^2\}$$
$$=(x+z)(x-z)(x^2+y^2+z^2).$$

Example 3. Resolve into factors $x^3+7x^2-21x-27$.

The given expression $=(x^3-27)+(7x^2-21x)$

$$=(x-3)(x^2+3x+9)+7x(x-3)$$
$$=(x-3)\{(x^2+3x+9)+7x\}$$
$$=(x-3)(x^2+10x+9)$$
$$=(x-3)(x+9)(x+1).$$

Example 4. Resolve into factors $4a^2+12ab+9b^2-8a-12b$

The given exp $=(4a^2+12ab+9b^2)-(8a+12b)$

$=(2a+3b)^2-4(2a+3b)$

$=(2a+3b)\{(2a+3b)-4\}$

$=(2a+3b)(2a+3b-4)$

Example 5. Resolve into factors $2a^2-2bc+6b^2+ac-7ab$

We observe that the 1st 3rd and the 5th terms are of the second degree in a and b, whilst the 2nd and the 4th terms are of the first degree in those letters

Putting the former set of terms in one group and the latter in another, we have the given expression

$=(2a^2-7ab+6b^2)+c(a-2b)$

$=(a-2b)(2a-3b)+c(a-2b)$

$=(a-2b)(2a-3b+c)$

Example 6. Resolve into factors $x^2-y^2-z^2+2yz+x+y-z$

The given exp $=(x^2-y^2-z^2+2yz)+(x+y-z)$

$=\{x^2-(y-z)^2\}+(x+y-z)$

$=(x+y-z)(x-y+z)+(x+y-z)$

$=(x+y-z)\{(x-y+z)+1\}$

$=(x+y-z)(x-y+z+1)$

Example 7. Resolve into factors

$$a^2x^3+a^5-2abx^3+b^2x^3+a^3b^2-2a^4b.$$

We observe that the 1st, 3rd and 4th terms have got x^3 for a common factor whilst the other have got a^3

Hence, putting the 1st, 3rd and 4th terms in one group and the remaining terms in another, we have the given expression

$=(a^2x^3-2abx^3+b^2x^3)+(a^5+a^3b^2-2a^4b)$

$=x^3(a^2-2ab+b^2)+a^3(a^2+b^2-2ab)$

$=(a^2-2ab+b^2)(x^3+a^3)$

$=(a-b)^2(x+a)(x^2-xa+a^2)$

EXERCISE 79.

Resolve into factors

1. x^3+x^2+x+1 **2.** x^3+x^2-x-1

3. x^3-x^2-x+1 **4.** $bc(a^2+1)+a(b^2+c^2)$

5. $x^4-ab^3+xb^3-x^3a$ **6.** $ab(x^2+y^2)+xy(a^2+b^2)$

7. $x^2+xy-yz-z^2$ **8.** $xb-ac-xc+ab$

9. $(2x^2+3b^2)a-(2a^2+3x^2)b$
10. $a(a+c)-b(b+c)$ 11. $4a^2+8ac-12bc-9b^2$
12. $a^2x^2+acxz-b^2y^2-bcyz$ 13. $x^4-y^3z+y^2x^2-y^2z^2$
14. $16x^2-15ab+12bx-25a^2$ 15. $a^2(a+2b)+b^2(2a+b)$
16. $m^3-2m^2n+2mn^2-n^3$ 17. $a^4+2a^3b-2ab^3-b^4$
18. $x^3(x-2y)+y^3(2x-y)$ 19. $a^3+5a^2+10a+8$
20. $x^3-17x^2+85x-125$ 21. $8a^3+18a^2b-27ab^2-27b^3$
22. $x^2-2xy+y^2-x+y$ 23. $4a^2-4ab+b^2-6a+3b$
24. $x^4-2ax^3+2a^2x^2-2a^3x+a^4$
25. $a^4-3a^3b+4a^2b^2-6ab^3+4b^4$
26. $a^2+3ab+2b^2+ac+2bc$ 27. $x^2-4xy+3y^2+xz-3yz$
28. $m^2+2pm-5mn-4pn+6n^2$
29. $a^2-10ab-15bc+21b^2+5ac$
30. $2x^2+4a(4b-3a)+x(4b+5a)$
31. $a^2-3a(2b-1)+4b(2b-3)$
32. $3x(x+2)-2y(4x-1)-3y^2$
33. $a^2-b^2-c^2-2bc+a-b-c$
34. $x^2-4y^2-9z^2+12yz+4x-8y+12z$
35. $9x^2-4z^2-24xy+16y^2+20y-15x+10z$
36. $2a^2x^4-5a^4x^2+3a^6-2b^2x^4+5a^2b^2x^2-3a^4b^2$
37. $2x^3+(2a-3b)x^2-(2b+3ab)x+3b^2$
38. $(a^2+b^2)x^2-a^2b(2a+b)+a(2bx^2-a^3)$
39. $2a^4-5a^3+6a^2-5a+2$
40. $a^5-4a^4-13a^3+13a^2+4a-1$
41. $2x^2+6xy+4y^2+5xz+6yz+2z^2$
42. $2x^2+xy-3y^2-xz-4yz-z^2$
43. $a^8-5a^6-12a^4-5a^2+1$
44. $4x^2-4xy-3y^2+12yz-9z^2$
45. $x^5-ax^4+a^2x^3-a^3x^2+a^4x-a^5$
46. $x^3+7x^2+14x+8$

148. Miscellaneous Examples.

Example 1. Resolve into factors $a^3+7ab^2-22b^3$

We find that the expression can be split up into parts each of which is divisible by $a-2b$ in either of the two following ways:

(i) $(a^3-8b^3)+7b^2(a-2b)$,

(ii) $a(a^2-4b^2)+11b^2(a-2b)$

Hence choosing the former way, we have

$$\begin{aligned}a^3+7ab^2-22b^3&=(a^3-8b^3)+7b^2(a-2b)\\&=(a-2b)\{(a^2+2ab+4b^2)+7b^2\}\\&=(a-2b)(a^2+2ab+11b^2)\end{aligned}$$

Example 2. Resolve into factors

$$x^2+2(a^2+b^2)+3ax-b(3x+5a)$$

Arranging the expression according to descending powers of x, we have it$=x^2+3(a-b)x+(2a^2-5ab+2b^2)$

$$\begin{aligned}&=x^2+3(a-b)x+(2a-b)(a-2b)\\&=x^2+\{(2a-b)+(a-2b)\}x+(2a-b)(b-2b)\\&=\{x+(2a-b)\}\{x+(a-2b)\}\\&=x\{x+(2a-b)\}+(a-2b)\{x+(2a-b)\}\\&=(x+2a-b)(x+a-2b)\end{aligned}$$

Example 3. Resolve into factors $x^2-6xy+8y^2-z^2+2yz$

The given expression$=(x^2-6xy+9y^2)-(y^2+z^2-2yz)$

$$\begin{aligned}&=(x-3y)^2-(y-z)^2\\&=\{(x-3y)+(y-z)\}\{(x-3y)-(y-z)\}\\&=(x-2y-z)(x-4y+z)\end{aligned}$$

Example 4. Resolve into factors $(a^2-b^2)(x^2-y^2)+4abxy$

The given expression

$$\begin{aligned}&=a^2x^2-a^2y^2-b^2x^2+b^2y^2+4abxy\\&=(a^2x^2+b^2y^2+2abxy)-(a^2y^2+b^2x^2-2abxy)\\&=(ax+by)^2-(ay-bx)^2\\&=\{(ax+by)+(ay-bx)\}\{(ax+by)-(ay-bx)\}\\&=\{(a-b)x+(a+b)y\}\{(a+b)x-(a-b)y\}\end{aligned}$$

Example 5. Resolve into factors $x^4+6x^3+4x^2-15x+6$

The given expression

$$\begin{aligned}&=(x^4+6x^3+9x^2)-(5x^2+15x)+6\\&=(x^2+3x)^2-5(x^2+3x)+6\\&=\{(x^2+3x)-2\}\{(x^2+3x)-3\}\\&=(x^2+3x-2)(x^2+3x-3)\end{aligned}$$

Example 6. Resolve into factors
$$x^4+2x^3y+3x^2y^2+2xy^3+y^4.$$

The given expression
$$=(x^4+2x^2y^2+y^4)+x^2y^2+(2x^3y+2xy^3)$$
$$=(x^2+y^2)^2+(xy)^2+2(xy)(x^2+y^2)$$
$$=\{(x^2+y^2)+xy\}^2=(x^2+xy+y^2)^2.$$

Example 7. Resolve into factors $(x-1)(x-2)(x+3)(x+4)+4$
$$(x-1)(x-2)(x+3)(x+4)$$
$$=\{(x-1)(x+3)\}\{(x-2)(x+4)\}$$
$$=(x^2+2x-3)(x^2+2x-8)$$

Hence, putting z for x^2+2x, the given expression
$$=(z-3)(z-8)+4$$
$$=z^2-11z+28=(z-4)(z-7)$$
$$=(x^2+2x-4)(x^2+2x-7)$$

Note *The student must carefully notice why in multiplying together the four binomials $x-1$, $x-2$, $x+3$, $x+4$, we combine $x+3$ with $x-1$, and $x+4$ with $x-2$*

Example 8. If $x+y=a$ and $xy=b^2$, find the value of (i) x^4+y^4 and (ii) $x^3-x^2y-xy^2+y^3$ in terms of a and b

(i) $x^4+y^4=(x^2+y^2)^2-2x^2y^2$
$$=\{(x+y)^2-2xy\}^2-2x^2y^2$$

and $\therefore$ the reqd value$=(a^2-2b^2)^2-2b^4=a^4-4a^2b^2+2b^4$

(ii) $x^3-x^2y-xy^2+y^3=x^2(x-y)-y^2(x-y)$
$$=(x-y)(x^2-y^2)$$
$$=(x-y)^2(x+y)$$
$$=\{(x+y)^2-4xy\}(x+y)$$
$$=(a^2-4b^2)a$$

Example 9. Find the value of $x^4-x^3+x^2+2$, when $x^2+2=2x$
$$x^4-x^3+x^2+2=(x^4+x^3+x^2)-2(x^3-1)$$
$$=x^2(x^2+x+1)-2(x-1)(x^2+x+1)$$
$$=(x^2+x+1)\{x^2-2(x-1)\}$$
$$=(x^2+x+1)(x^2-2x+2)$$

and the required value$=(x^2+x+1)\times 0=0$

Example 10. Find the value of

$$a^4+b^4+c^4-2b^2c^2-2c^2a^2-2a^2b^2, \text{ when } a+b=c$$

The given expression

$$=-(2b^2c^2+2c^2a^2+2a^2b^2-a^4-b^4-c^4)$$

$$=-(a+b-c)(a-b+c)(a+b+c)(b+c-a) \quad \text{[Art 142]}$$

and $\cdot =0$, when $a+b=c$

EXERCISE 80.

Resolve into factors·

1. $x^3+8x^2+19x+12$ **2.** $x^3+9x^2+26x+24$

3. $x^3-6x^2+11x-6$ **4.** $x^3+5x^2-2x-24$

5. x^3-4x^2+x+2 **6.** x^3+5x^2-2x-6

7. $x^3-6x^2+13x-10$ **8.** $x^4-3x^3-9x^2+12x+20$

9. $x^4-3x^3-x^2+13x-10$ **10.** $x^4-5x^3+x^2+13x+6$

11. $x^4+5x^3-8x^2-30x+36$ **12.** $x^4-7x^3+9x^2+26x-56$

13. $x^3-7x^2+13x-15$ **14.** $x^3-5x+12.$

15. x^3-6x^2+32 **16.** $2x^3-3x^2-4$

17. $x^3-9xy^2-10y^3$ **18.** $a^3+4a^2b-9b^3$

19. $5a^3-3a^2b-28b^3$ **20.** $8x^3+4x-3$

21. $2x^3+5x^2-4x-3$ **22.** x^3-3x-2

23. $2a^3-a^2b-b^3$ **24.** $3x^3+8x^2-8x-3$

25. $x^3-6xy^2+9y^3.$ **26.** $x^2+bx-(a^2-3ab+2b^2)$

27. $a^4+4abx^2y^2-(a^2-b^2)^2y^4.$

28. $a^4+2(x^2+y^2)a^2b^2+(x^2-y^2)^2b^4$

29. $a^2+(x+y)a-2x^2+5xy-2y^2$

30. $x(x+a)-2a^2+3b(a+x)+2b^2$

31. $x^2+4xy+3y^2+2yz-z^2$

32. $4a^2-4ab-3b^2+12bc-9c^2$

33. $x^4+6x^3+8x^2+6x-9$

34. $a^4-4a^3b-5a^2b^2+6ab^3-b^4$

35. $4x^4-20x^3+24x^2+6x-9$

36. $x^4-2x^3+2x^2-2x+1$ **37.** $a^4-9a^2+30a-25$

38. $a^2-2abx-(ac-b^2)x^2+bcx^3$

39. $x^4y^4+x^2y^2-z^2+2xyz+1$

40. $x^2(y^2-z^2)+4xyz-y^2+z^2$

41. $(a^2-b^2)(x^2+y^2)+2(a^2+b^2)xy$

42. $x^4-4x^3-x^2+10x+4$ **43.** $a^4-6a^3+15a^2-18a+5.$

44. $4x^4+12x^3-5x^2-21x+12$

45. $x^4-5x^3y+6x^2y^2-5xy^3+y^4$

46. $x^4-5x^3+14x^2-20x+16$

47. $a^4-7a^3b+14a^2b^2-14ab^3+4b^4$

48. $x^4+4x^3-11x^2+20x+25$

49. $a^4+4a^3b-10a^2b^2+4ab^3+b^4$

50. $x^4+8x^3+24x^2+32x-20$

51. $(x+1)(x+3)(x-4)(x-6)+13$

52. $(x+2)(x+3)(x+4)(x+5)-360$

53. $x(2x+1)(x-2)(2x-3)-63$

54. Find the value of $xy(x+y)+yz(y+z)+zx(z+x)+3xyz$, when $x=a(b-c)$, $y=b(c-a)$, $z=c(a-b)$

55. Find the value of $(y-z)(y^2-z^2)-x\{(y-z)^2+x(y+z)\}+x^3$. when $x=a^2-b^2$ $y=b^2-c^2$, $z=a^2-c^2$

56. Find the value of $x^2-2(y-2)x-3y^2+20y-32$, when $x+y=4$

57. Find the value of $x^2-y^2+4x+14y-45$, when $x+y=25$ and $x-y=6$

58. Find the value of $8xy(x^2+y^2)$, $\left.\begin{array}{l}\text{when } x+y=\sqrt{3}\\ \text{when } x-y=\sqrt{2}\end{array}\right\}$.

II. Identities.

149. We shall in this section consider some important identities of a somewhat harder type than those treated of in Chapter XIII and establish their truth with the aid of the foregoing formulæ and principles

The following general method should be remembered

Reduce the more difficult side of the identity to the form of the other with the help of the preceding formulæ

If both the sides of the identity are complex reduce each to its simplest form and establish their equality

Sometimes an identity follows easily by transposition of terms or addition of some terms to both its sides

Sometimes an identity may be proved very easily by substituting a new letter for a group of letters occurring in the identity Make such substitutions wherever necessary

The following examples will illustrate the process ·

Example 1. Prove that

$$(x-a)(x-b)(a-b)+(x-b)(x-c)(b-c)+(x-c)(x-a)(c-a)$$
$$=-(b-c)(c-a)(a-b)$$

Substituting p for $x-a$, q for $x-b$ and r for $x-c$, we have

$$q-p=a-b, r-q=b-c, p-r=c-a$$

The left side $=pq(q-p)+qr(r-q)+rp(p-r)$

$=-(q-p)(r-q)(p-r)$

$=-(a-b)(b-c)(c-a)$, [restoring values of $q-p, r-q, p-r$]

Example 2. Prove that $(y+z)^2(2x+y+z)+(z+x)^2(x+2y+z)$
$+(x+y)^2(x+y+2z)+2(y+z)(z+x)(x+y)$
$=(2x+y+z)(x+2y+z)(x+y+2z)$

Putting a for $y+z$, b for $z+x$, c for $x+y$, we have

$$b+c=2x+y+z,\ c+a=x+2y+z,\ a+b=x+y+2z$$

The left side $=a^2(b+c)+b^2(c+a)+c^2(a+b)+2abc$

$=(b+c)(c+a)(a+b)$

$=(2x+y+z)(x+2y+z)(x+y+2z)$

Example 3. Prove that $x^3+6(y+z)x^2+12(y+z)^2x+8(y+z)^3$
$=4(3x+2y+6z)y^2+(x+6y+2z)(x+2z)^2$ [M M 1881]

$$\begin{aligned}
\text{The left side} &= x^3+3x^2\{2(y+z)\}+3x\{2(y+z)\}^2+\{2(y+z)\}^3 \\
&= [x+\{2(y+z)]^3=(x+2y+2z)^3 \\
&= \{2y+(x+2z)\}^3 \\
&= (2y)^3+3(2y)^2(x+2z)+3(2y)(x+2z)^2+(x+2z)^3 \\
&= 8y^3+12y^2(x+2z)+6y(x+2z)^2+(x+2z)^3 \\
&= 4y^2\{2y+3(x+2z)\}+\{6y+(x+2z)\}(x+2x)^2 \\
&= 4(3x+2y+6z)y^2+(x+6y+2z)(x+2z)^2.
\end{aligned}$$

Example 4. Prove that $x^3+y^3+z^3+24xyz$

$$=(x+y+z)^3-3\{x(y-z)^2+y(z-x)^2+z(x-y)^2\}.$$

By transposition of terms, this identity is equivalent to the form

$$\begin{aligned}
&3\{x(y-z)^2+y(z-x)^2+z(x-y)^2\}+24xyz \\
&=(x+y+z)^3-x^3-y^3-z^3 \qquad (1)
\end{aligned}$$

If the latter identity can be established, the former can be deduced by transposing terms.

$$\begin{aligned}
\text{Now, } &3\{x(y-z)^2+y(z-x)^2+z(x-y)^2\}+24xyz \\
&=3\{x(y^2-2yz+z^2)+y(z^2-2zx+x^2) \\
&\qquad +z(x^2-2xy+y^2)\}+24xyz \\
&=3\{x(y^2+z^2)+y(z^2+x^2)+z(x^2+y^2)-2xyz \\
&\qquad -2yzx-2zxy+8xyz\} \\
&=3\{x(y^2+z^2)+y(z^2+x^2)+z(x^2+y^2)+2xyz\} \\
&=3(y+z)(z+x)(x+y)=(x+y+z)^3-x^3-y^3-z^3
\end{aligned}$$

$\therefore$ by transposition, $x^3+y^3+z^3+24xyz$

$$=(x+y+z)^3-3\{x(y-z)^2+y(z-x)^2+z(x-y)^2\}.$$

Example 5. Prove that $-x(b-c)(c-a)(a-b)$

$$=a(b-c)(x-b)(x-c)+b(c-a)(x-c)(x-a)+c(a-b)(x-a)(x-b);$$

The 1st expression of the right side

$$\begin{aligned}
&=a(b-c)\{x^2-x(b+c)+bc\} \\
&=x^2a(b-c)-xa(b^2-c^2)+abc(b-c)
\end{aligned}$$

The 2nd expression of the right side

$$\begin{aligned}
&=b(c-a)\{x^2-x(c+a)+ca\} \\
&=x^2b(c-a)-xb(c^2-a^2)+abc(c-a)
\end{aligned}$$

The 3rd expression $= c(a-b)\{x^2 - x(a+b) + ab\}$
$$= x^2c(a-b) - xc(a^2-b^2) + abc(a-b)$$

The right side (adding the columns vertically)

$$= x^2\{a(b-c)+b(c-a)+c(a-b)\} - x\{a(b^2-c^2)$$
$$+b(c^2-a^2)+c(a^2-b^2)\} + abc\{(b-c)+(c-a)+(a-b)\}$$
$$= x^2\cdot 0 - x\{(b-c)(c-a)(a-b)\} + abc\cdot 0,$$

[Formulæ XXII, XIV and XXIII, Art 133]

$$= -x(b-c)(c-a)(a-b)$$

Example 6. Prove that

$$(1-x^2)(1-y^2)(1-z^2) - (x+yz)(y+zx)(z+xy)$$
$$= (1+xyz)(1-x^2-y^2-z^2-2xyz)$$

The left side

$$= (1-x^2)(1-y^2)(1-z^2) - \frac{(xyz+x^2)}{x}\cdot\frac{(xyz+y^2)}{y}\cdot\frac{(xyz+z^2)}{z}$$
$$= \{1-(x^2+y^2+z^2)+y^2z^2+z^2x^2+x^2y^2-x^2y^2z^2\} - \frac{1}{xyz}\{(xyz)^3$$
$$+(xyz)^2(x^2+y^2+z^2)+(xyz)(y^2z^2+z^2x^2+x^2y^2)+x^2y^2z^2\}$$
$$= (1-x^2-y^2-z^2)+(y^2z^2+z^2x^2+x^2y^2)-x^2y^2z^2-x^2y^2z^2$$
$$-xyz(x^2+y^2+z^2)-(y^2z^2+z^2x^2+x^2y^2)-xyz$$
$$= (1-x^2-y^2-z^2)-xyz-xyz(x^2+y^2+z^2)-2x^2y^2z^2$$
$$= 1-x^2-y^2-z^2-2xyz+xyz-xyz(x^2+y^2+z^2)-2x^2y^2z^2$$
$$= (1-x^2-y^2-z^2-2xyz)+xyz(1-x^2-y^2-z^2-2xyz)$$
$$= (1+xyz)(1-x^2-y^2-z^2-2xyz)$$

150. Conditional Identities. We shall now establish certain important *Conditional* identities and deduce the truth of other identities from them

151. If $a+b+c=0$, prove that

(1) $a^2+b^2+c^2 = -2(bc+ca+ab)$

We have $(a+b+c)^2 = a^2+b^2+c^2+2bc+2ca+2ab$

$$\therefore\quad 0^2 = a^2+b^2+c^2+2(bc+ca+ab)$$

Transposing $a^2+b^2+c^2 = -2(bc+ca+ab)$

(2) $a^3+b^3+c^3=3abc$

We have $a^3+b^3+c^3-3abc$

$$=(a+b+c)(a^2+b^2+c^2-bc-ca-ab)$$
$$=0\times(a^2+b^2+c^2-bc-ca-ab)=0$$

Transposing, $a^3+b^3+c^3=3abc$ [See Art 99, Ex 10]

(3) $(bc+ca+ab)^2=b^2c^2+c^2a^2+a^2b^2=\frac{1}{4}(a^2+b^2+c^2)^2$

We have $(bc+ca+ab)^2=b^2c^2+c^2a^2+a^2b^2+2abc(a+b+c)$

$$=b^2c^2+c^2a^2+a^2b^2+2abc\times 0$$
$$=b^2c^2+c^2a^2+a^2b^2$$

Also, from (1) above, $bc+ca+ab=-\frac{1}{2}(a^2+b^2+c^2)$

$$(bc+ca+ab)^2=\frac{1}{4}(a^2+b^2+c^2)^2$$

Hence, $(bc+ca+ab)^2=b^2c^2+c^2a^2+a^2b^2=\frac{1}{4}(a^2+b^2+c^2)^2$

(4) $a^4+b^4+c^4=2(b^2c^2+c^2a^2+a^2b^2)$
$$=\frac{1}{2}(a^2+b^2+c^2)^2$$

We have $2b^2c^2+2c^2a^2+2a^2b^2-a^4-b^4-c^4$

$$=(a+b+c)(b+c-a)(c+a-b)(a+b-c)$$
$$=0\times(b+c-a)(c+a-b)(a+b-c) \qquad \text{[Art 142]}$$
$$=0$$

Hence, transposing,

$$a^4+b^4+c^4=2b^2c^2+2c^2a^2+2a^2b^2=2(b^2c^2+c^2a^2+a^2b^2)$$
$$=\frac{1}{2}(a^2+b^2+c^2)^2 \qquad \text{[from (3)]}$$

(5) $a^5+b^5+c^5=-5abc(bc+ca+ab)$
$$=\frac{5}{2}abc(a^2+b^2+c^2)$$
$$=\frac{5}{6}(a^2+b^2+c^2)(a^3+b^3+c^3)$$

Since, $a+b+c=0$, we have by transposition $a+b=-c$

$$(a+b)^5=(-c)^5,$$

or, $a^5+5a^4b+10a^3b^2+10a^2b^3+5ab^4+b^5=-c^5$ [Art 127]

By transposition, $a^5+b^5+c^5$

$$=-5a^4b-10a^3b^3-10a^2b^3-5ab^4$$
$$=-5ab(a^3+2a^2b+2ab^2+b^3)$$
$$=-5ab(a+b)(a^2+ab+b^2), \qquad \text{[factorising]}$$
$$=-5ab(-c)\{(a+b)^2-ab\}, \qquad [\text{since } a+b=-c]$$

$$=5abc\{(a+b)(-c)-ab\}$$
$$=5abc(-ac-bc-ab)$$
$$=-5abc(bc+ca+ab)$$
$$=\frac{5abc}{2}(a^2+b^2+c^2) \qquad \text{[by (1)]}$$
$$=\tfrac{5}{6}(a^2+b^2+c^2)\,3abc$$
$$=\tfrac{5}{6}(a^2+b^2+c^2)(a^3+b^3+c^3)$$
[since, $a^3+b^3+c^3=3abc$]

(6) $a^7+b^7+c^7=7abc(bc+ca+ab)^2$
$$=\tfrac{7}{12}(a^2+b^2+c^2)(a^3+b^3+c^3)$$

Since, $a+b+c=0$, we have by transposition, $a+b=-c$
$$(a+b)^7=(-c)^7,$$
or, $a^7+7a^6b+21a^5b^2+35a^4b^3+35a^3b^4+21a^2b^5+7ab^6+b^7$
$$=-c^7 \qquad \text{[Art 127]}$$

Transposing, $a^7+b^7+c^7$
$$=-7a^6b-21a^5b^2-35a^4b^3-35a^3b^4-21a^2b^5-7ab^6$$
$$=-7ab(a^5+3a^4b+5a^3b^2+5a^2b^3+3ab^4+b^5)$$
$$=-7ab(a+b)(a^4+2a^3b+3a^2b^2+2ab^3+b^4)$$
[factorising]
$$=-7ab(-c)(a^2+ab+b^2)^2$$
$$=7abc(a^2+ab+b^2)^2$$
$$=7abc(bc+ca+ab)^2 \qquad \text{[as in (5)]}$$
$$=\tfrac{7}{3}(bc+ca+ab)^2\,3abc$$
$$=\frac{7}{3}\cdot\left(\frac{a^2+b^2+c^2}{2}\right)^2\cdot(a^3+b^3+c^3) \qquad \text{[from (2) \& (3)]}$$
$$=\tfrac{7}{12}(a^2+b^2+c^2)^2(a^3+b^3+c^3)$$

Example 1. Prove that $(y-z)^3+(z-x)^3+(x-y)^3$
$$=3(y-z)(z-x)(x-y)$$

Putting a for $(y-z)$, b for $(z-x)$ and c for $(x-y)$,
we have $\quad a+b+c=y-z+z-x+x-y=0$
$$a^3+b^3+c^3=3abc \qquad \text{[by (3)]}$$

Restoring values of a, b and c, $(y-z)^3+(z-x)^3+(x-y)^3$
$$=3(y-z)(z-x)(x-y)$$

Example 2. Prove that $\frac{(y-z)^5+(z-x)^5+(x-y)^5}{5}$

$$=\frac{(y-z)^2+(z-x)^2+(x-y)^2}{2}\cdot\frac{(y-z)^3+(z-x)^3+(x-y)^3}{3}.$$

Put, a for $(y-z)$, b for $(z-x)$ and c for $(x-y)$, we have

$$a+b+c=y-z+z-x+x-y=0,$$

$$a^5+b^5+c^5=\tfrac{5}{6}(a^2+b^2+c^2)(a^3+b^3+c^3),$$

[from (5)]

or, $$\frac{a^5+b^5+c^5}{5}=\frac{a^2+b^2+c^2}{2}\cdot\frac{a^3+b^3+c^3}{3}.$$

Restoring values of a, b, c, we obtain

$$\frac{(y-z)^5+(z-x)^5+(x-y)^5}{5}=\frac{(y-z)^2+(z-x)^2+(x-y)^2}{2}$$
$$\times\frac{(y-z)^3+(z-x)^3+(x-y)^3}{3}.$$

Example 3. Prove that $(y+z-x)^3+(z+x-y)^3+(x+y-z)^3$ $=3(y+z-x)(z+x-y)(x+y-z)=-24xyz$, if $x+y+z=0$

Putting a for $y+z-x$, b for $z+x-y$ and c for $x+y-z$,

we have $a+b+c=(y+z-x)+(z+x-y)+(x+y-z)$
$$=x+y+z=0$$

Hence, $a^3+b^3+c^3=3abc$

Restoring values of a, b, c, we obtain

$$(y+z-x)^3+(z+x-y)^3+(x+y-z)^3$$
$$=3(y+z-x)(z+x-y)(x+y-z)$$

Also since $a+b+c=0$, we have by transposition,

$$a=-(b+c)=-\{(z+x-y)+(x+y-z)\}=-2x,$$
$$b=-(c+a)=-\{(x+y-z)+(y+z-x)\}=-2y,$$
$$c=-(a+b)=-\{(y+z-x)+(z+x-y)\}=-2z$$

$$3abc=3(-2x)(-2y)(-2z)=-24xyz$$

or, $3(y+z-x)(z+x-y)(x+y-z)=-24xyz$

Hence, $(y+z-x)^3+(z+x-y)^3+(x+y-z)^3$
$$=3(y+z-x)(z+x-y)(x+y-z)=-24xyz$$

Example 4. If $x=a^2-bc$, $y=b^2-ca$, $z=c^2-ab$, show that

$$x^3+y^3+z^3-3xyz=(a^3+b^3+c^3-3abc)^2$$

We have
$$\begin{aligned} x+y+z &= a^2-bc+b^2-ca+c^2-ab \\ &= a^2+b^2+c^2-bc-ca-ab, \end{aligned}$$

$$\begin{aligned} y-z &= b^2-ca-(c^2-ab) \\ &= b^2-c^2+ab-ca \\ &= (b-c)(b+c)+a(b-c) \\ &= (b-c)\{(b+c)+a\} \\ &= (b-c)(a+b+c) \end{aligned}$$

Similarly,
$$\begin{aligned} z-x &= (c-a)(a+b+c) \\ x-y &= (a-b)(a+b+c) \end{aligned}$$

Now,
$$\begin{aligned} & x^3+y^3+z^3-3xyz \\ &= \tfrac{1}{2}(x+y+z)\{(y-z)^2+(z-x)^2+(x-y)^2\} \\ &= \tfrac{1}{2}(a^2+b^2+c^2-bc-ca-ab)\{(b-c)^2(a+b+c)^2 \\ &\qquad +(c-a)^2(a+b+c)^2+(a-b)^2(a+b+c)^2\} \\ &= (a^2+b^2+c^2-bc-ca-ab) \\ &\qquad \times\tfrac{1}{2}\{(b-c)^2+(c-a)^2+(a-b)^2\}(a+b+c)^2 \\ &= (a+b+c)^2(a^2+b^2+c^2-bc-ca-ab)^2 \\ &= \{(a+b+c)(a^2+b^2+c^2-bc-ca-ab)\}^2 \\ &= (a^3+b^3+c^3-3abc)^2 \end{aligned}$$

Example 5. If $s=a+b+c$, prove that

$$\begin{aligned} s(s-2b)(s-2c)+s(s-2c)(s-2a)+s(s-2a)(s-2b) \\ =(s-2a)(s-2b)(s-2c)+8abc \end{aligned}$$

The sum of the first two terms of the left side
$$\begin{aligned} &= s(s-2c)\{(s-2b)+(s-2a)\} \\ &= s(s-2c)\{2s-2(a+b)\} \\ &= s(s-2c)\times 2c, \end{aligned}$$

and the third term
$$\begin{aligned} &= \overline{(s-2c+2c)}(s-2a)(s-2b) \\ &= (s-2c)(s-2a)(s-2b)+2c(s-2a)(s-2b) \end{aligned}$$

Hence, the left side
$$\begin{aligned} &= s(s-2c)2c+\{(s-2c)(s-2a)(s-2b)+2c(s-2a)(s-2b)\} \\ &= (s-2a)(s-2b)(s-2c)+2c\{s(s-2c)+(s-2a)(s-2b)\} \end{aligned}$$

But $s(s-2c)+(s-2a)(s-2b)$

$$=(s^2-2cs)+\{s^2-2s(a+b)+4ab\}$$
$$=2s^2-2s(a+b+c)+4ab$$
$$=2s^2-2s\,s+4ab$$
$$=4ab$$

$\therefore$ The left side $=(s-2a)(s-2b)(s-2c)+8abc$

Example 6. If $s=a+b+c$, show that $(s-a)(s-b)(s-c)$
$$=(a+b+c)(bc+ca+ab)-abc$$

The left side $=s^3-(a+b+c)s^2+(bc+ca+ab)s-abc$
$$=s^3-s\,s^2+(bc+ca+ab)(a+b+c)-abc$$
$$=(bc+ca+ab)(a+b+c)-abc$$

Example 7. If $a+b+c+d=0$, prove that $(a+b)(a+c)(a+d)$
$$=(b+a)(b+d)(b+c)$$
$$=(c+d)(c+a)(c+b)$$
$$=(d+c)(d+b)(d+a)$$

Since $a+b+c+d=0$, we have, by transposition
$$a+b=-(c+d),$$
$$a+c=-(b+d)$$
$$a+d=-(b+c),$$
$$(a+b)(a+c)(a+d)$$
$$=(a+b)\{-(b+d)\}\{-(b+c)\}$$
$$=(a+b)(b+d)(b+c)$$
$$=(b+a)(b+d)(b+c)$$

Similarly, $(a+b)(a+c)(a+d)$
$$=\{-(c+d)\}(a+c)\{-(b+c)\}$$
$$=(c+d)(a+c)(b+c)$$
$$=(c+d)(c+a)(c+b),$$
$$(a+b)(a+c)(a+d)=-(c+d)\{-(b+d)\}(a+d)$$
$$=(c+d)(b+d)(a+d)$$
$$=(d+c)(d+b)(d+a)$$

Example 8. Prove that
$$(y+z-x)^3+(z+x-y)^3+(x+y-z)^3+24xyz$$
$$=(2x+y-z)^3+(y+z)^3-(x+y-z)^3-6x(x-2z)(x+y)$$

Putting a for $2x+y-z$, b for $y+z$ and c for $-(x+y-z)$,

we have
$$a+b+c=x+y+z,$$
$$b+c=2z-x,$$
$$c+a=x,$$
$$a+b=2(x+y)$$

The right side

$=(2x+y-z)^3+(y+z)^3+\{-(x+y-z)\}^3+3\,x(2z-x)\,2(x+y)$

$=a^3+b^3+c^3+3(c+a)(b+c)(a+b)$

$=(a+b+c)^3$

$=(x+y+z)^3$, [restoring values of a, b, c]

$=\{(y+z-x)+(z+x-y)+(x+y-z)\}^3$, [since $(y+z-x)+(z+x-y)+(x+y-z)=x+y+z$]

$=(y+z-x)^3+(z+x-y)^3+(x+y-z)^3+3\{(z+x-y)+(x+y-z)\}\{(x+y-z)+(y+z-x)\}\{(y+z-x)+(z+x-y)\}$

[Formula XVII, Art 133]

$=(y+z-x)^3+(z+x-y)^3+(x+y-z)^3+3\,2x\,2y\,2z$

$=(y+z-x)^3+(z+x-y)^3+(x+y-z)^3+24xyz$

EXERCISE 81.

Prove that

1. $a^2x+b^2y+c^2z=(x+y+z)(a^2+b^2+c^2)$,
if $x^2-yz=a^2$, $y^2-zx=b^2$, $z^2-xy=c^2$

2. $ax+by+cz=(a+b+c)(x+y+z)$,
if $x=a^2-bc$, $y=b^2-ca$, $z=c^2-ab$

3. $(x-a)^2(b-c)+(x-b)^2(c-a)+(x-c)^2(a-b)+(b-c)(c-a)(a-b)=0.$

4. $27(a+b+c)^3-(a+2b)^3-(b+2c)^3-(c+2a)^3=3(a+3b+2c)(b+3c+2a)(c+3a+2b).$

5. $2(s-a)(s-b)(s-c)+a(s-b)(s-c)+b(s-c)(s-a)+c(s-a)(s-b)=abc$, if $2s=a+b+c$

6. $s(s-a)(s-b)+s(s-a)(s-c)+s(s+a)(s-c)+c(s+a)(s+b)=(s+a)(s+b)(s+c)$ if $s=a+b+c.$

7. $(s-a)^3+(s-b)^3+(s-c)^3-3(s-a)(s-b)(s-c)$
$$=\tfrac{1}{2}(a^3+b^3+c^3-3abc), \text{ if } 2s=a+b+c$$

8. $(3x+2y+5z)^3-(3x+2y-5z)^3-30z\{(3x+2y)^2-25z^2\}$
$$=(20x-y+8z)^3+(y+2z-20x)^3$$
$$+30z(20x-y+8z)(y+2z-20x)$$

9. $(x+y+2z)(x+2y+z)(2x+y+z)-(y+z)(z+x)(x+y)$
$$=2(x+y+z)^3+2xyz$$

10. $(a+b+c)(x+y+z)+(a+b-c)(x+y-z)+(b+c-a)$
$$(y+z-x)+(c+a-b)(z+x-y)=4(ax+by+cz)$$

11. $(y-z)(1+xy)(1+xz)+(z-x)(1+yz)(1+yx)$
$$+(x-y)(1+zx)(1+yz)=(y-z)(z-x)(x-y)$$

12. $(x-1)(x^2+x+4)(y-z)+(y-1)(y^2+y+4)(z-x)$
$$+(z-1)(z^2+z+4)(x-y)=-(y-z)(z-x)(x-y)(x+y+z)$$

13. $x^3+y^3+z^3+w^3+3(y+z)(z+x)(x+y)=0,$
$$\text{if } x+y+z+w=0.$$

14. $$\frac{(b-c)^5+(c-a)^5+(a-b)^5}{5}\cdot\frac{(b-c)^2+(c-a)^2+(a-b)^2}{2}$$
$$=\frac{(b-c)^7+(c-a)^7+(a-b)^7}{7}.$$

15. $(x+y)(x+z)(x^2-yz)=(x+y+z)(x-z)(x^2+y^2),$
if $x=a^3+a^2, y=a^2+a$ and $z=a+1.$ [M U 1909]

16. $(y+z-2x)(z+x-2y)+(z+x-2y)(x+y-2z)$
$$+(x+y-2z)(y+z-2x)$$
$$=3\{(y-z)(z-x)+(z-x)(z-y)+(x-y)(y-z)\}$$

17. $(y-z)^4+(z-x)^4+(x-y)^4=2(x^2+y^2+z^2-yz-zx-xy)^2$

18. $(b-c)(b+c-2a)^3+(c-a)(c+a-2b)^3$
$$+(a-b)(a+b-2c)^3=0$$

19. $x^3(y-z)^3+y^3(z-x)^3+z^3(x-y)^3$
$$=3xyz(y-z)(z-x)(x-y)$$

20. $a^6(b^2-c^2)^3+b^6(c^2-a^2)^3+c^6(a^2-b^2)^3$
$$=3a^2b^2c^2(b+c)(c+a)(a+b)(b-c)(c-a)(a-b)$$

21. $(b+c)(b-c)^3+(c+a)(c-a)^3+(a+b)(a-b)^3$
$$=2(b-c)(c-a)(a-b)(a+b+c)$$

22. $x(y-z)^3+y(z-x)^3+z(x-y)^3$
$$=(y-z)(z-x)(x-y)(x+y+z)$$

23. $4(a^2+ab+b^2)^3-(a-b)^2(a+2b)^2(2a+b)^2$
$$=27a^2b^2(a+b)^2$$

24. $2b^2c^2+2c^2a^2+2a^2b^2-a^4-b^4-c^4$
$$=16s(s-a)(s-b)(s-c), \text{ if } 2s=a+b+c$$

25. $(s-a)^3+(s-b)^3+(s-c)^3+3abc=s^3$, if $2s=a+b+c$

26. $$\frac{(b-c)^3+(c-a)^3+(a-b)^3}{3}\cdot\frac{(b-c)^7+(c-a)^7+(a-b)^7}{7}$$
$$=\left\{\frac{(b-c)^5+(c-a)^5+(a-b)^5}{5}\right\}^2.$$

27. $(ax+by+cz)^2+(bx+cy+az)^2+(cx+ay+bz)^2$
$$-\{(bx+cy+az)(cx+ay+bz)+(cx+ay+bz)(ax+by+cz)$$
$$+(ax+by+cz)(bx+cy+az)\}$$
$$=(a^2+b^2+c^2-bc-ca-ab)(x^2+y^2+z^2-yz-zx-xy)$$

28. $(ax+by+cz)^3+(bx+cy+az)^3+(cx+ay+bz)^3$
$$-3(ax+by+cz)(bx+cy+az)(cx+ay+bz)$$
$$=(a^3+b^3+c^3-3abc)(x^3+y^3+z^3-3xyz)$$

If $a+b+c=0$, prove that

29. $ca-b^2=ab-c^2=bc-a^2=bc+ca+cb=-\frac{1}{2}(a^2+b^2+c^2)$

30. $b^2+bc+c^2=c^2+ca+a^2=a^2+ab+b^2=-(bc+ca+ab)$

31. $a(c+a)(a+b)=b(a+b)(b+c)=c(a+c)(b+c)=abc$

32. $a(b+c)^2+b(c+a)^2+c(a+b)^2=3abc$

33. $a(b-c)^3+b(c-a)^3+c(a-b)^3=0$

34. $X^3+Y^3+Z^3=3XYZ$, where $X=ax+by+cz$,
$Y=bx+cy+az$ and $Z=cx+ay+bz$

35. $(2a+b+c)^3+(a+2b+c)^3+(a+b+2c)^3$
$$=3(2a+b+c)(a+2b+c)(a+b+2c)$$

36. Prove that $(3x+y+z)^3+(x+3y+z)^3+(x+y+3z)^3$
$$-3(3x+y+z)(x+3y+z)(x+y+3z)=20(x^3+y^3+z^3-3xyz)$$

37. If $a+b+c=1$, prove that $(a+bc)(b+c)$
$$=(b+ca)(c+a)=(c+ab)(a+b)=(1-a)(1-b)(1-c)$$

Prove that

38. $(x+y)^2(y+z-x)(z+x-y)+(x-y)^2(x+y+z)(x+y-z)$
$$=4xyz^2+(y^2-z^2)(y^4+y^2z^2+z^4)+(z^2-x^2)(z^4+z^2x^2+x^4)$$
$$+(x^2-y^2)(x^4+x^2y^2+y^4)$$

39. $2x(y+z-x)+(z+x-y)(x+y-z)=2y(z+x-y)$
$$+(x+y-z)(y+z-x)=2z(x+y-z)+(y+z-x)(z+x-y)$$
$$=(y+z-x)(z+x-y)+(z+x-y)(x+y-z)$$
$$+(x+y-z)(y+z-x)$$

40. $x^3+y^3+z^3=a^3-3ab+3c$,

when $x+y+z=a$, $yz+zx+xy=b$, $xyz=c$

41. $yz(y+z)+zx(z+x)+xy(x+y)+3xyz$
$=\frac{1}{2}(p^3-pq^2)$, when $x+y+z=p$ and $x^2+y^2+z^2=q^2$

42. $x^7+y^7+z^7=7qr^2$

when $x+y=-z$, $xyz=q$, $yz+zx+xy=r$

43. $x^4+y^4+z^4=\frac{1}{2}q^4$,

when $x^2+y^2+z^2=q^2$, $x+y=13$, $z=-13$

44. $(x+y+z)(yz+zx+xy)-(y+z)(z+x)(x+y)=120$,

when $yz=45$, $zx=64$, $xy=5$

CHAPTER XXIII

THE REMAINDER THEOREM AND DIVISIBILITY

152. Important Theorem in Division.

Theorem 1. *If px^2+qx+r is divided by $x-a$ until the remainder does not contain x, the remainder will be pa^2+qa+r.*

By actual division, we have

$$\begin{array}{r|l|l} x-a & px^2+qx+r & px+(ap+q) \\ & \underline{px^2-apx} & \\ & (ap+q)x+r & \\ & \underline{(ap+q)x-a(ap+q)} & \\ & a(ap+q)+r & \end{array}$$

$\therefore$ The remainder $=a(ap+q)+r=pa^2+qa+r$

Note *Observe that the remainder is of the same form as the dividend with a in the place of x*

Theorem II. *If* px^3+qx^2+rx+s *is divided by* $x-a$ *until the remainder does not involve* x, *the remainder will be* pa^3+qa^2+ra+s

By actual division,

$$
\begin{array}{r|l|l}
x-a & px^3+qx^2+rx+s & px^2+(ap+q)x+(pa^2+qa+r) \\
 & \underline{px^3-apx^2} & \\
 & (ap+q)x^2+rx+s & \\
 & \underline{(ap+q)x^2-a(ap+q)x} & \\
 & (pa^2+qa+r)x+s & \\
 & \underline{(pa^2+qa+r)x-a(pa^2+qa+r)} & \\
 & pa^3+qa^2+ra+s &
\end{array}
$$

∴ The remainder required $=pa^3+qa^2+ra+s$

Note *Here also, notice that the remainder is of the same form as the dividend with a in the place of x*

Example 1. Find the remainder independent of x when x^3-5x^2+6x+9 is divided by $x-2$

By Theorem II, the remainder required

$$
\begin{aligned}
&= \text{the value of } x^3-5x^2+6x+9 \text{ when } x=2 \\
&=2^3-5\cdot 2^2+6\cdot 2+9 \\
&=8-20+12+9=9
\end{aligned}
$$

Example 2. Find the remainder independent of x when x^3-216 is divided by $x-6$

The remainder required = the value of x^3-216 when $x=6$
$=6^3-216=216-216=0$

Note *The student is recommended to verify these results by actual division*

153. Rational and integral Expessions. We shall now establish a more general theorem known as the **Remainder Theorem** by dividing an expression of the type $px^n+qx^{n-1}+rx^{n-2}+ \dots +lx+m$ by $x-a$, n being a *positive integer* and $p, q, r, \dots l, m$ being constants

An algebraic expression of this kind in which every power of x is a *positive integer* is called a **rational and integral expression** in x

Thus, $x^2-3x+13$, x^3+px+r, etc are each a rational and integral expression in x

154. The Remainder Theorem. *If any rational and integral expression in x is divided by $x-a$, the remainder independent of x, is obtained by putting a for x in the given expression*

Let $px^n+qx^{n-1}+rx^{n-2}+ \quad +lx+m$ be the rational and integral expression Let Q be the quotient and R, the remainder *independent of x* when the above expression is divided by $x-a$

Then, since, (Dividend) = (Divisor) × (Quotient) + (Remainder), we have $px^n+qx^{n-1}+rx^{n-2}+ \quad +lx+m$

$$=(x-a)Q+R \text{ (identically)}$$

Since R does not contain x, it remains the same whatever value be given to x If a is put for x in the above relation, we have

$$pa^n+qa^{n-1}+ra^{n-2}+ \quad +la+m=(a-a)Q'+R,$$

(where Q' is the value of Q when a is put for x)

$$=0\times Q'+R=0+R$$
$$=R$$

∴ The remainder $R=pa^n+qa^{n-1}+ra^{n-2}+ \quad +la+m$

Thus, the remainder is of the same form as the dividend with a in the place of x

Hence, the theorem is established.

Cor. *If any rational and integral expression in x be divided by $x+a$, the remainder independent of x* is obtained by putting *$-a$ for x in the given expression*

Since, $x+a=x-(-a)$, the above corollary follows at once from the Remainder Theorem

Example 1. If x^2-5x+9 be divided by $x+2$, find the remainder independent of x

From the corollary, the remainder required = the value of the expression x^2-5x+9, when -2 is put for x

$$=(-2)^2-5(-2)+9=4+10+9=23$$

Example 2. If x^2+px+q be divided by $x+a$, find the remainder independent of x

From the corollary above, the remainder required

$$=\text{the value of } x^2+px+q, \text{ when } x=-a$$
$$=(-a)^2+p(-a)+q=a^2-pa+q$$

Note. *The student is advised to verify these results by actual division*

Example 3. Find, without actual substitution, the value of $x^6-19x^5+69x^4-151x^3+229x^2+166x+26$, when $x=15$.

By the remainder theorem, the value of the expression when 15 is put for x

$$=\text{the remainder on division by } x-15$$

But the given expression

$$=x^6-15x^5-(4x^5-60x^4)+(9x^4-135x^3)$$
$$-(16x^3-240x^2)-(11x^2-165x)+(x-15)+41$$
$$=x^5(x-15)-4x^4(x-15)+9x^3(x-15)-16x^2(x-15)$$
$$-11x(x-15)+(x-15)+41$$

Evidently, the remainder on division by $x-15=41$

Hence, the value required $=41$

155. Divisibility and Factor Theorem. *If any rational and integral expression in x vanishes identically when a is substituted for x, the expression is exactly divisible by $x-a$ and contains $x-a$ as a factor*

Let the given expression be $px^n+qx^{n-1}+rx^{n-2}+\quad+lx+m$

The remainder on division by $x-a$

$=$the value of the dividend when a is put for x, [by the Remainder Theorem.]

$$=pa^n+qa^{n-1}+ra^{n-2}+\quad+la+m$$

The given expression is exactly divisible by $x-a$ if the remainder is zero,

i e if $pa^n+qa^{n-1}+ra^{n-2}+\quad+la+m=0$.

Also, $\therefore$ (Dividend) = (Divisor) × (Quotient) + Remainder, we have the given expression

$$=(x-a)\times Q+(pa^n+qa^{n-1}+ra^{n-2}+\quad\quad +la+m),$$

[Q being the quotient]

$$=(x-a)Q,\quad \text{if } pa^n+qa^{n-2}+\quad\quad +la+m=0$$

$x-a$ is a factor of $px^n+qx^{n-1}+\quad\quad +lx+m$ if

$$pa^n+qa^{n-1}+\quad\quad +la+m=0$$

Thus, the theorem is established

Cor. $x+a$ is a factor of $px^n+qx^{n-1}+rx^{n-2}+\quad .. +lx+m$, if $p(-a)^n+q(-a)^{n-1}+r(-a)^{n-2}+\quad +l(-a)+m=0$

Since, $x+a=x-(-a)$, the corollary follows at once

Example 1. Show that $3x^3-2x^2+x-18$ is exactly divisible by $x-2$ and contains $x-2$ as a factor.

The value of $3x^3-2x^2+x-18$ when 2 is put for x

$$=3\cdot 2^3-2\cdot 2^2+2-18=24-8+2-18=0$$

Hence, by the above theorem, $3x^3-2x^2+x-18$ is exactly divisible by $x-2$ and contains $x-2$ as a factor

Example 2. Show that $3x^3-2x^2y-13xy^2+10y^3$ is exactly divisible by $x-2y$

Putting $2y$ for x in the given expression, we have

$$3(2y)^3-2(2y)^2y-13(2y)y^2+10y^3$$
$$=24y^3-8y^3-26y^3+10y^3=0$$

$\therefore$ By the above theorem, the given expression is exactly divisible by $x-2y$ and contains $x-2y$ as a factor

Example 3. Find the condition that the rational and integral expression $ax^n+bx^{n-1}+cx^{n-2}+\quad\quad +lx+m$ may be divisible by $x-1$

The value of the given expression when 1 is put for x

$$=a\,1^n+b\,1^{n-1}+c\,1^{n-2}+\quad\quad\quad +l\,1+m$$
$$=a+b+c+\quad\quad .\quad\quad +l+m$$

[since, $1^n=1\times 1\times 1$ to n factors $=1$
and similarly $1^{n-1}=1^{n-2}=\quad ..=1$]

$\therefore$ The given expression is exactly divisible by $x-1$,

if $a+b+c+ \quad +l+m=0$,

i e if the algebraic sum of the co-efficients of the expression be zero.

Example 4. Prove that $x+3$ is a factor of x^3+4x^2+5x+6

$$x+3=x-(-3)$$

The value of x^3+4x^2+5x+6, when $x=-3$

$$=(-3)^3+4(-3)^2+5(-3)+6$$
$$=-27+36-15+6=0$$

Hence, by the corollary of the factor theorem the expression is exactly divisible by $x+3$ and contains $x+3$ as a factor

Example 5. If the expression x^3+3x^2+4x+p contains $x+6$ as a factor, find p.

$$x+6=x-(-6)$$

The value of x^3+3x^2+4x+p for $x=-6$

$$=(-6)^3+3(-6)^2+4(-6)+p$$
$$=-216+108-24+p$$
$$=p-132$$

By the above theorem, $(x+6)$ is a factor, if $p-132=0$

. the reqd value of $p=132$

Example 6. Find the condition that x^2+3x+p and x^2+4x+q may have a common factor

Let $x-a$ be the common factor

Putting a for x, the value of x^2+3x+p

$$=a^2+3a+p=0 \qquad (1)$$

[since, $x-a$ is a factor of x^2+3x+p]

Similarly, $a^2+4a+q=0 \qquad (2)$

[since $x-a$ is a factor of x^2+4x+q]

From (1) and (2), by subtraction, we have

$$(a^2+4a+q)-(a^2+3a+p)=0,$$

or, $a+q-p=0$,

or, $a=p-q$ [transposing]

Substituting this value of a in (1), we have

$$0=a^2+3a+p=(p-q)^2+3(p-q)+p$$
$$=p^2-2pq+q^2+4p-3q$$

The required condition is $p^2-2pq+q^2+4p-3q=0$

156. Important Theorems on Divisibility. In Chapter X we have already considered the divisibility of expressions a^n+b^n and a^n-b^n by $a+b$ and $a-b$ in particular cases We propose now to establish the propositions generally

Theorem I. *The expression a^n-b^n is always divisible by $a-b$, if n is **any** positive integer, odd or even*

Divide a^n-b^n by $a-b$ until the remainder is independent of a Let Q be the quotient and R, the remainder

Since, (Dividend) = (Quotient) × (Divisor) + (Remainder),

we have, $a^n-b^n=Q\times(a-b)+R$ (*identically*)

Now, since R is independent of a, it remains the same whatever value be given to a

Let $a=b$ in the above relation Then, we have

$b^n-b^n=Q'\times(b-b)+R$, [Q' being the value of Q when b is put for a]

or, $\quad 0=Q'\times 0+R=0+R$,

$R=0$

Hence, the remainder being zero, a^n-b^n is exactly divisible by $a-b$

Thus, if the division be actually performed we have $a^n-b^n=(a-b)(a^{n-1}+a^{n-2}b+a^{n-3}b^2+\quad\quad+ab^{n-2}+b^{n-1})$

Example. Each of the expressions a^2-b^2, a^3-b^3, a^4-b^4, a^5-b^5, etc is exactly divisible by $a-b$

Theorem II. *The expression a^n-b^n is exactly divisible by $a+b$ when n is any **even** positive integer, but not if n is odd*

Divide a^n-b^n by $a+b$ until the remainder does not contain a Then, if Q be the quotient and R, the remainder, we have

$$a^n-b^n=Q\times(a+b)+R \text{ (identically)}$$

Since R does not contain a, it remains the same whatever value be given to a. Putting $-b$ for a in the above identity, we have $(-b)^n - b^n = Q' \times (-b+b)+R$, [$Q'$ being the value of Q when $-b$ is put for a]

$$= Q' \times 0 + R = R.$$

when n is even. $(-b)^n - b^n = b^n - b^n = 0$,

when n is odd. $(-b)^n - b^n = -b^n - b^n = -2b^n$

$\therefore$ $R=0$, when n is even:

but, since $R=-2b^n$, when n is odd, the remainder is not zero, when n is an odd integer

Hence $a^n - b^n$ is exactly divisible by $a+b$ when n is even but not if n is odd

Thus, by actual division, we have

$$a^n - b^n = (a+b)(a^{n-1} - a^{n-2}b + a^{n-3}b^2 - \qquad + ab^{n-2} - b^{n-1}),$$

when n is even

Example. Each of the expressions a^2-b^2, a^4-b^4, a^6-b^6, etc is exactly divisible by $a+b$; but a^3-b^3, a^5-b^5, a^7-b^7, etc are *not* exactly divisible by $a+b$

Theorem III. *The expression a^n+b^n is exactly divisible by $a+b$ if n is* **odd**, *but not if n be even.*

Divide a^n+b^n by $a+b$ till the remainder does not contain a Let Q be the quotient and R, the remainder. Then,

$$a^n + b^n = Q \times (a+b) + R \ (\textit{identically}).$$

Since R does not contain a, it remains the same whatever value be given to a Let $a=-b$ in the above identity Then, we have,

$$(-b)^n + b^n = Q' \times (-b+b) + R = Q' \times 0 + R = R,$$

when n is odd, $(-b)^n + b^n = -b^n + b^n = 0$

But, when n is even $(-b)^n + b^n = b^n + b^n = 2b^n$, which is therefore, not zero.

Hence, $R=0$ if n is odd but not if n is even

$\therefore$ a^n+b^n is exactly divisible by $a+b$ when n is odd but not when n is even.

Thus by actual division, we have,

$$a^n + b^n = (a+b)(a^{n-1} - a^{n-2}b + a^{n-3}b^2 \ . \ . \ - ab^{n-2} + b^{n-1}),$$

when n is odd

Example. a^3+b^3, a^5+b^5, a^7+b^7 are all exactly divisible by $a+b$, while a^2+b^2, a^4+b^4, a^6+b^6 are not so

Theorem IV. *The expression a^n+b^n is never divisible by $a-b$, whether n is even or odd*

Divide a^n+b^n by $a-b$ until the remainder does not contain a Let Q be the quotient and R, the remainder Then,

$$a^n+b^n=Q\times(a-b)+R \text{ (identically)}.$$

Since, R does not contain a, it remains the same whatever value be given to a Put b for a in the above identity and we have $b^n+b^n=Q'\times(b-b)+R=Q'\times 0+R=R$;

or, $R=2b^n$

Since, R does not vanish for any value of n, a^n+b^n is never divisible by $a-b$

Example. Thus a^2+b^2, a^3+b^3, a^4+b^4, etc are never divisible by $a-b$

Example 1. Show that $3^{4n}-4^{3n}$ is divisible by 17, if n is any positive integer

The expression $3^{4n}-4^{3n}=(3^4)^n-(4^3)^n=(81)^n-(64)^n$

. By Theorem I, Art 156, the given expression is divisible by $81-64$, i e 17

Example 2. Show that the last two digits of $2^{6n}-6^{2n}$ are 0 s, n being any even positive integer.

The given expression $=(2^6)^n-(6^2)^n=(64)^n-(36)^n$.

Since n is even, the given expression is exactly divisible by $64+36$ i e by 100 [Theorem II Art. 156]

Hence, 100 being a factor of the given expression, the last two digits must be 0's

Example 3. Show that

$$(x^3+3ax^2+3a^2x+a^3)^{2m+1}+(x^3-3ax^2+3a^2x-a^3)^{2m+1}$$

contains $2x$ as a factor m being a positive integer

The given expression $=\{(x+a)^3\}^{2m+1}+\{(x-a)^3\}^{2m+1}$

$$=(x+a)^{3(2m+1)}+(x-a)^{3(2m+1)}$$

Since $3(2m+1)$ is an odd positive integer the given expression is exactly divisible by $(x+a)+(x-a)$, i e $2x$ [Theorem III]

Example 4. Show that $(b-c)^{2n+1}+(c-a)^{2n+1}+(a-b)^{2n+1}$ is divisible by $(b-c)(c-a)(a-b)$, n being any positive integer

The given expression is a rational and integral expression in a, b and c

If we substitute c for b in the expression, we have the expression

$$\begin{aligned}&=(c-c)^{2n+1}+(c-a)^{2n+1}+(a-c)^{2n+1}\\&=(0)^{2n+1}\quad+(c-a)^{2n+1}+\{-(c-a)\}^{2n+1}\\&=0\qquad\quad+(c-a)^{2n+1}-(c-a)^{2n+1}\end{aligned}$$

[Now, $\{-(c-a)\}^{2n+1}$

$$\begin{aligned}&=\{-1\times(c-a)\}^{2n+1}\\&=\{-1\times(c-a)\}\times\{-1\times(c-a)\}\times\quad\text{to }(2n+1)\text{ factors}\\&=(-1)\times(-1)\times(-1)\quad\text{to }(2n+1)\text{ factors}\\&\qquad\times(c-a)\times(c-a)\times(c-a)\quad\text{to }(2n+1)\text{ factors}\\&=-1\times(c-a)^{2n+1}=-(c-a)^{2n+1}\end{aligned}$$

∴ the expression $=0$,

∴ By Art 155, the given expression is divisible by $b-c$

Similarly, putting a for c in the given expression, it may be shown that the expression is divisible by $c-a$, and putting b for a, it may be shown that the given expression is divisible by $a-b$

Hence, the given expression is divisible by the product $(b-c)(c-a)(a-b)$

Example 5. If n be any positive integer, show that

$(ab)^n-(bc)^n+(cd)^n-(da)^n$ is divisible by $ab-bc+cd-da$

[M M 1873]

Evidently, $ab-bc+cd-da=b(a-c)+d(c-a)=(c-a)(d-b)$

Now, if we put a for c in the given expression, we have

$$\begin{aligned}\text{the expression}&=(ab)^n-(ba)^n+(ad)^n-(da)^n\\&=(ab)^n-(ab)^n+(ad)^n-(ad)^n\\&=0\end{aligned}$$

∴ By Art 155, the given expression is exactly divisible by $c-a$

Similarly, putting b for d in the expression, it may be shown that the expression is divisible by $d-b$

∴ The expression is divisible by the product of $c-a$ and $d-b$

i e by $(c-a)(d-b)$

i.e by $ab-bc+cd-da$

Example 6. Show that $x^{n+1}-x^n-x+1$ is exactly divisible by $(x-1)^2$, when n is any positive integer

The given expression $=x^{n+1}-x^n-x+1=x^n(x-1)-(x-1)$
$$=(x-1)(x^n-1)$$

Thus, $x-1$ is a factor of the given expression

Since, by Theorem I, Art 155, x^n-1 is exactly divisible by $x-1$

The given expression is divisible by $(x-1)\times(x-1)$ i e $(x-1)^2$

Example 7. Find the continued product of
$$(x+a)(x^2+a^2)(x^4+a^4)(x^8+a^8).$$

Let A denote the continued product required

Then, $A=(x+a)(x^2+a^2)(x^4+a^4)(x^8+a^8)$.

Multiplying both the sides by $x-a$, we have

$$(x-a)\,A=\{(x-a)(x+a)\}(x^2+a^2)(x^4+a^4)(x^8+a^8)$$
$$=\{(x^2-a^2)(x^2+a^2)\}(x^4+a^4)(x^8+a^8)$$
$$=\{(x^4-a^4)(x^4+a^4)\}(x^8+a^8)$$
$$=(x^8-a^8)(x^8+a^8)=x^{16}-a^{16},$$
$$A=\frac{x^{16}-a^{16}}{x-a}=x^{15}+x^{14}a+x^{13}a^2+\qquad+xa^{14}+a^{15}$$

Example 8. If $x+a$ be the H C F of x^2+px+q and $x^2+p'x+q'$, show that $a=\dfrac{q-q'}{p-p'}$.

Since $x+a$ is the H C F of the two expressions x^2+px+q and $x^2+p'x+q'$, these expressions must be exactly divisible by $x+a$

∴ By the Divisibility Theorem, we have

$$(-a)^2+p(-a)+q=0, \quad i\,e, \quad a^2-pa+q=0,$$
and $$(-a)^2-p'(-a)+q'=0, \quad i\,e, \quad a^2-p'a+q'=0,$$
∴ By subtraction, $(a^2-p'a+q')-(a^2-pa+q)=0$,

or, $a(p-p')+q'-q=0$

Transposing, $a(p-p')=q-q'$;

$$\therefore \quad a=\frac{q-q'}{p-p'}.$$

EXERCISE 82.

Find the remainder, without actual division, when

1. $x^4+2x^3+3x^2+4x+5$ is divided by $x-3$

2. $3x^9+5x^7+11$ is divided by $x+1$

3. $3x^3+7x^2+11x+2$ is divided by $3x-1$

4. $4x^3+5x^2+9x+7$ is divided by $2x+3$

5. ax^3+bx^2+cx+d is divided by $ax+b$

In the following examples, show that the first expression is divisible by the second

6. $6x^3+13x^2+17x+6$ by $2x+1$

7. $apx^3+(2p+aq)x^2+(2q+ar)x+2r$ by $ax+2$

8. $6x^4+13x^3y+18x^2y^2+23xy^3+10y^4$ by $3x+2y$

9. $a^{57}+b^{57}$ by $a+b$

10. $64x^6-729y^6$ by $2x+3y$

11. $x^{2n}-y^{2n}$ by $x+y$ (n being a positive integer)

12. $x^{12}y^8-x^8y^{12}$ by $x^2y^2(x-y)$

13. $(3a+2b)^{2n+1}+b^{2n+1}$ by $a+b$
(n being any positive integer)

14. $x^{2n+1}-ax^{2n}-xa^{2n}+a^{2n+1}$ by $(x-a)^2$

15. $64+32x+2x^5+x^6$ by x^2+4x+4

16. Find the condition that $x^7+9x^4-7x^3+11ax+5a^2$ may contain $x+1$ as a factor

17. For what values of a will $3x^5+9x^4-7x^3-5x^2-4ax+3a^2$ contain $x-1$ as a factor?

18. What must be the form of m in order that a^m-x^m may have both a^n+x^n and a^n-x^n for divisors, n being any positive integer? [M M 1875]

19. If n be any positive integer, show that
$(x^2+7x+6)^n-(2+x)^{2n}$ is divisible by $3x+2$

20. Show that the quotient of $3x^3+x^2-11x+7$ when divided by $x-1$ is exactly divisible by $x-1$

Show that each of the following expressions is exactly divisible by $(a-a)(b-c)(c-a)$

21. $a^2b^2(a-b)+b^2c^2(b-c)+c^2a^2(c-a)$

22. $a^3b^3(a-b)+b^3c^3(b-c)+c^3a^3(c-a)$

23. $a^2(b-c)^3+b^2(c-a)^3+c^2(a-b)^3$

24. $(a-b)^9+(b-c)^9+(c-a)^9$

25. $a^7b^7(a-b)^{69}+b^7c^7(b-c)^{69}+c^7a^7(c-a)^{69}$

26. Show, by the principle of divisibility that $(a+b+c)(ab+bc+ca)-abc$ contains the factors $b+c$, $c+a$ and $a+b$

27. Show that $(ax+by)(bx+cy)(cx+ay)-(ay+bx)(by+cx)(cy+ax)$ contains the factors $x-y$, $a-b$, $b-c$ and $c-a$

[M U 1874]

28. Show that $a^n(b-c)+b^n(c-a)+c^n(a-b)$ contains each of the factors $a-b$, $b-c$ and $c-a$ [P U. 1916]

29. Resolve $a^3(b^2-c^2)+b^3(c^2-a^2)+c^3(a^2-b^2)$ into factors by the principle of divisibility

30. Show that $a^4(b^2-c^2)+b^4(c^2-a^2)+c^4(a^2-b^2)$ is divisible by $(b+c)(c+a)(a+b)(a-b)(b-c)(c-a)$

31. Show that the last digit in $(41)^n-1$, where n is any positive integer, is zero

32. Show that $7^{2m}-1$, where m is any positive integer, is divisible by each of the factors, 2, 3, 4, 6, 8, 12, 16, 24 and 48

33. Show that $17^8+13^7-5^8+2^7$ is divisible by 3

34. Show that x^3-x-6 and $x^3-11x+14$ contain a common factor of the form $x-m$

35. Show that the expression $(81)^m(121)^m-1$, where m is any positive integer is divisible by 100

36. Find the continued product of

$$(1+x)(1+x^2)(1+x^4)(1+x^8)(1+x^{16})$$

37. Show that $13^n=12(13^{n-1}+13^{n-2}+\quad+1)+1$, n being any positive integer

38. Find the continued product of $11\times101\times10001$

39. Show that $x^n-nx+n-1$ is exactly divisible by $(x-1)^2$

40. Show that $a^m(a-1)+b^m(b-1)$ is not divisible by $a+b$, m being any positive integer

Write down the quotients in the following divisions

41. x^5+y^5 by $x+y$ **42.** x^6-y^6 by $x+y$

43. x^7-y^7 by $x-y$ **44.** $x^{16}-y^{16}$ by x^2+y^2.

45. $x^{16}-y^{16}$ by $x-y$

46. If $x+3$ be the H C F of $ax^3+5x+2p$ and $ax^3+3x+p+6$, find p and a

47. If $x-5$ be the H C F. of bx^2-px+5 and $bx^2-2x-2p$, prove that $p=5$ and $b=\frac{4}{5}$

48. If $x-a$ be the H C F of qx^2+2x+p and qx^2+x+r, prove that $a=r-p$ and $q(r-p)^2+2r-p=0$

49. Find, without actual substitution the value of $x^9-3x^8+5x^7-15x^6+13x^5-39x^4+7x^3-21x^2+17x-51$, when $x=3$

50. What is the value of $32x^5-48x^4+40x^3-60x^2+26x-38$, when $x=1\ 5$?

CHAPTER XXIV

HARDER H.C.F. AND L.C.M.

157. In Chapters XIV and XV we have explained the methods of finding the H C F and the L C M of compound expressions, whose factors can be determined easily We shall now proceed to consider more difficult cases

I. Harder Highest Common Factors.

158. If the H C F of two or more compound expressions be a compound expression, it cannot generally be found by inspection In such cases the following methods should be adopted

159. The ordinary method of finding the H.C.F. of two multinomial expressions which have no monomial factors.

Rule. *Arrange the two expressions according to descending powers of some common letter, divide the expression which is of higher degree, in that letter by the other, or if they be of the same degree, either of them by the other, if there be any remainder,*

take it for a new divisor and the preceding divisor for the dividend, and continue the process till there is no remainder The last divisor will be the H C F required Of any divisor and the corresponding dividend either may be multiplied or divided by any number which is not a factor of the other

This rule may be proved as follows

Let A and B stand for two such expressions both arranged according to descending powers of some common letter* and let the index of the highest power of that letter in A be not less than the index of the highest power of that letter in B

Divide A by B and let Q be the quotient and C the remainder

Then we must have $C = A - BQ$ (1)

or, $A = BQ + C$. (2)

From (1) it is clear that every common factor of A and B is a factor of C [for if $A = pa$ and $B = pb$, we have $C = p(a - bQ)$]. Hence, if H denote the H C F of A and B, H also is a factor of C, and is therefore a *common factor* of B and C

It is clear therefore that the H C F of B and C is either H or an expression of higher dimensions than H (α)

Now from (2), it is evident that *every* common factor of B and C is a factor of A and is therefore a common factor of B and A Hence, the H C F of B and C also is a common factor of B and A and therefore cannot be of higher dimensions than H

Hence, from (α), the H C F of B and C is H

Thus the H C F. of B and C is the H C F required

Similarly, if B be divided by C, and D be the new remainder, the H C F of C and D is the same as the H.C F of B and C and is therefore the H C F required

Now divide C by D and let there be no remainder Then D is the H C F of C and D and is therefore the H C F required

Cor. 1. As the H C F of any divisor and the corresponding dividend is the H C F required, it is clear that, for the sake

*The letter is called the *letter of reference.*

of convenience, either of them may be multiplied or divided by any monomial expression *which is not a factor of the other*
[See Note 8, Art 100]

Cor. 2. In dividing A by B if we stop before the complete* quotient is obtained so that q is the partial quotient and C' the corresponding remainder, then the H C F of B and C' just as the H C F of B and C is the H C F required Hence, by Cor 1, in dividing C' by B (or if convenient, B by C' when C' is *not* of higher degree than B) we can multiply or divide either of them, if necessary, by any monomial expression *which is not a factor of the other*

The following examples will illustrate the process

Example 1. Find the H C F of $3x^3-7x^2-18x-8$ and $2x^3-3x^2-17x-12$

The H C F required is evidently the H C F of $3x^3-7x^2-18x-8$ and $3(2x^3-3x^2-17x-12)$ [Cor 1] Let us therefore multiply the 2nd expression by 3 and divide the product by the 1st,

$$
\begin{array}{r|l|l}
 & 2x^3-\ 3x^2-17x-12 & \\
 & 3 & \\
\hline
3x^3-7x^2-18x-8 & 6x^3-\ 9x^2-51x-36 & 2 \\
 & 6x^3-14x^2-36x-16 & \\
\hline
 & \qquad 5x^2-15x-20 &
\end{array}
$$

Hence, the H C F required is the H C F of $3x^3-7x^2-18x-8$ and $5x^2-15x-20=5(x^2-3x-4)$ and is therefore the H C F of $3x^3-7x^2-18x-8$ and x^2-3x-4 [Cor 1]

We must proceed then as follows

$$
\begin{array}{r|l|l}
 & 5)5x^2-15-20 & \\
\hline
x^2-3x-4 & 3x^3-7x^2-18x-8 & 3x+2 \\
 & 3x^3-9x^2-12x & \\
\hline
 & \qquad 2x^2-\ 6x-8 & \\
 & \qquad 2x^2-\ 6x-8 & \\
\hline
\end{array}
$$

Hence, the H C F required $=x^2-3x-4$

Example 2. Find the H C F, of

$$22x^6-78x^5-16x^2 \text{ and } 2x^5-78x^2-44x$$

The 1st expression $=2x^2(11x^4-39x^3-8)$

The 2nd expression $=2x(x^4-39x-22)$

*The quotient obtained is said to be complete when the remainder is of lower degree in the letter of reference than the divisor

Hence by Note 7, Art 100, the H C F required
$=$(the H C F of $2x^2$ and $2x$) $\times$ (the H C F of
$11x^4-39x^3-8$ and $x^4-39x-22$)
$=2x\times X$, putting X for the H C F of the multinomials.

Now let us find X, as in the last example;

$$\begin{array}{r|l|l}
x^4-39x-22 & 11x^4-\ \ 39x^3-\ \ 8 & 11 \\
 & 11x^4-429x\ \ -242 & \\
\hline
 & -3)\ -\ 39x^3+429x+234 & \\
 & 13)\ \ 13x^3-143x\ -\ 78 & \\
 & \qquad x^3-\ \ 11x\ -\ \ 6 &
\end{array}$$

$$\begin{array}{r|l|l}
x^3-11x-6 & x^4-39x\ \ -22 & x \\
 & x^4-11x^2-6x & \\
\hline
 & 11)\ 11x^2-33x-22 & \\
 & \qquad x^2-\ 3x-\ 2 &
\end{array}$$

$$\begin{array}{r|l|l}
x^2-3x-2 & x^3-11x\ \ -6 & x+3 \\
 & x^3-\ \ 3x^2-2x & \\
\hline
 & 3x^2-9x-6 & \\
 & 3x^2-9x-6 & \\
\hline
\end{array}$$

Thus $X=x^2-3x-2$

Hence, the H C F. required$=2x(x^2-3x-2)$

Example 3. Find the H C F of

$12x^4a^2+54x^3a^3+6x^2a^4-72xa^5$ and

$8x^6a+60x^5a^2+160x^4a^3+180x^3a^4+72x^2a^5$.

The first exp $=6xa^2(2x^3+9x^2a+xa^2-12a^3)$

The 2nd exp $=4x^2a(2x^4+15x^3a+40x^2a^2+45xa^3+18a^4)$

Hence, if X denote the H C F of the multinomial factors of the given expressions, we must have the required H C F. $=$(the H C F. of $6xa^2$ and $4x^2a$) $\times X=2xa\times X$

Now to find X.

$$\begin{array}{r|l|l}
2x^3+9x^2a+xa^2-12a^3 & 2x^4+15x^3a+40x^2a^2+45xa^3+18a^4 & x \\
 & 2x^4+\ \ 9x^3a+\ \ \ \ x^2a^2-12xa^3 & \\
\hline
 & 3a)6x^3a+39x^2a^2+57xa^3+18a^4 & \\
 & \quad 2x^3+13x^2a\ \ +19xa^2+\ \ 6a^3 &
\end{array}$$

Hence, X is the H C F of $2x^3+9x^2a+xa^2-12a^3$ and $2x^3+13x^2a+19xa^2+6a^3$, and as they are both of the same degree we can divide either of them by the other

$$\begin{array}{r|l|l}
2x^3+9x^2a+xa^2-12a^3 & 2x^3+13x^2a+19xa^2+6a^3 & 1 \\
 & \underline{2x^3+9x^2a+xa^2-12a^3} & \\
 & 2a)\,4x^2a+18xa^2+18a^3 & \\
 & \quad 2x^2+9xa+9a^2 &
\end{array}$$

$$\begin{array}{r|l|l}
2x^2+9xa+9a^2 & 2x^3+9x^2a+xa^2-12a^3 & x \\
 & \underline{2x^3+9x^2a+9xa^2} & \\
 & -4a^2)\,-8xa^2-12a^3 & \\
 & \quad 2x+3a &
\end{array}$$

$$\begin{array}{r|l|l}
2x+3a & 2x^2+9xa+9a^2 & x+3a \\
 & \underline{2x^2+3xa} & \\
 & 6xa+9a^2 & \\
 & \underline{6xa+9a^2} &
\end{array}$$

Thus $X=2x+3a$

Hence, the H C F required $=2xa(2x+3a)$

Example 4. Find the H C F of
$4x^4+11x^3+27x^2+17x+5$ and $6x^4+14x^3+36x^2+14x+10$

The second expression $=2(3x^4+7x^3+18x^2+7x+5)$, but 2 is not a factor of the 1st expression Hence, the H C F required is the H C F of the 1st expression and $3x^4+7x^3+18x^2+7x+5$

$$\begin{array}{r|l|l}
 & 4x^4+11x^3+27x^2+17x+5 & \\
 & \underline{3} & \\
3x^4+7x^3+18x^2+7x+5 & 12x^4+33x^3+81x^2+51x+15 & 4 \\
 & \underline{12x^4+28x^3+72x^2+28x+20} & \\
 & 5x^3+9x^2+23x-5 &
\end{array}$$

$$\begin{array}{r|l|l}
 & 3x^4+7x^3+18x^2+7x+5 & \\
 & \underline{5} & \\
5x^3+9x^2+23x-5 & 15x^4+35x^3+90x^2+35x+25 & 3x \\
 & \underline{15x^4+27x^3+69x^2-15x} & \\
 & 8x^3+21x^2+50x+25 & \\
 & \underline{5} & \\
 & 40x^3+105x^2+250x+125 & 8 \\
 & \underline{40x^3+72x^2+184x-40} & \\
 & 33)\,33x^2+66x+165 & \\
 & \quad x^2+2x+5 &
\end{array}$$

$$
\begin{array}{r|l}
x^2+2x+5 & 5x^3+9x^2+23x-5 \;\big(\; 5x-1 \\
 & \underline{5x^3+10x^2+25x} \\
 & \quad -x^2-2x-5 \\
 & \quad \underline{-x^2-2x-5}
\end{array}
$$

Thus the required H C F $=x^2+2x+5$

Example 5. Find the H C F. of

$4x^4-16x^3+108$ and $6x^5-14x^3-40x^2+36$

The first expression $=4(x^4-4x^3+27)$

The second expression $=2(3x^5-7x^3-20x^2+18)$

Hence, if X denote the H C F of the multinomial factors of the given expressions, the H C F required $=2X$

Let us then find X

$$
\begin{array}{r|l}
x^4-4x^3+27 & 3x^5-7x^3-20x^2+18 \;\big(\; 3x+12 \\
 & \underline{3x^5-12x^4+81x} \\
 & \quad 12x^4-7x^3-20x^2-81x+18 \\
 & \quad \underline{12x^4-48x^3 \qquad\qquad +324} \\
 & \qquad 41x^3-20x^2-81x-306
\end{array}
$$

$$
\begin{array}{r|l}
 & \quad x^4-4x^3+27 \\
 & \quad \underline{41} \\
41x^3-20x^2-81x-306 & 41x^4-164x^3+1107 \;\big(\; x \\
 & \underline{41x^4-20x^3-81x^2-306x} \\
 & -9)\,\underline{-144x^3+81x^2+306x+1107} \\
 & \qquad 16x^3-9x^2-34x-123 \\
 & \qquad \underline{41} \\
 & 656x^3-369x^2-1394x-5043 \;\big(\; 16 \\
 & \underline{656x^3-320x^2-1296x-4896} \\
 & -49)\,\underline{-49x^2-98x-147} \\
 & \qquad x^2+2x+3
\end{array}
$$

$$
\begin{array}{r|l}
x^2+2x+3 & 41x^3-20x^2-81x-306 \;\big(\; 41x-102 \\
 & \underline{41x^3+82x^2+123x} \\
 & \quad -102x^2-204x-306 \\
 & \quad \underline{-102x^2-204x-306}
\end{array}
$$

Hence, the H C F. required $=2(x^2+2x+3)$

EXERCISE 83.

Find the H C F of

1. $2x^2+5x-3$ and $2x^3+3x^2-32x+15$
2. $3x^2+16x-12$ and $3x^3+4x^2-28x+16$

3. $2x^2-3ax-20a^2$ and $2x^3+3ax^2-45a^2x-100a^3$

4. $3x^4+7x^3-14x^2-24x$ and $6x^4-10x^3-24x^2$

5. $6a^3-11a^2-3a+2$ and $3a^3+20a^2+23a-10$

6. $6a^3-25a^2b+32ab^2-12b^3$ and $4a^3+12a^2b-7ab^2-30b^3$

7. $3x^3+5x^2+5x+2$ and $2x^3+5x^2+5x+3$

8. $4x^3-7x^2y+7xy^2-3y^3$ and $3x^3-7x^2y+7xy^2-4y^3$

9. $6x^4+7x^3+5x^2+2x$ and $4x^5-18x^4-8x^3-10x^2$

10. $3x^4+10x^3+7x^2+4x+1$ and $2x^3+3x^2-7x-3$

11. $4x^3+13x^2-8x-3$ and $3x^4+13x^3+9x^2+9x+2$

12. $12a^3+11a^2x+6ax^2+x^3$ and $21a^3+17a^2x+9ax^2+x^3$

13. $35a^3+31a^2x+13ax^2+2x^3$ and $65a^3+54a^2x+22ax^2+3x^3$

14. $70x^3-9ax^2+11a^2x+6a^3$ and $91x^3-25ax^2+20a^2x+4a^3$

15. $75x^3-35x^2+24x+4$ and $85x^3-36x^2+25x+6$

16. $35x^3-34x^2+3x+2$ and $49x^3-49x^2+5x+3$

17. $4x^6+2ax^5+14a^2x^4+10a^3x^3+24a^4x^2$ and $6x^6+21ax^5+30a^2x^4+24a^3x^3$

18. $4a^4+32a^3+72a^2+44a+8$ and $6a^4+54a^3+138a^2+78a+12$

19. $2x^4-19x^2+21x-6$ and $6x^4+21x^3+3x-6$

20. $12x^4-30x^2+126x+90$ and $15x^4-25x^3+145x-75$

21. $18x^4+117x^3+162x^2+72x+9$ and $12x^4+68x^3+72x^2+108x+20$

22. $x^5-5x^2+6x+12$ and $x^4-8x^2-24x-32$

23. $x^4+5x^3+3x^2-14x-40$ and $x^5-4x^3+45x+75$

24. $4x^5-8x^3a^2+28x^2a^3-24xa^4+24a^5$ and $6x^4+24x^3a-12x^2a^2-24xa^3+96a^4$

25. $9x^4-18x^3y-13x^2y^2-38xy^3-12y^4$ and $6x^5+4x^4y+5x^3y^2+4x^2y^3+8y^5$

26. $2x^5-11x^2-9$ and $4x^5+11x^4+81$

27. $32a^4+104a^3-20a^2-122a+30$ and $60a^5+10a^4-45a^3+45a^2-50a$

28. $x^5+2x^4-5x^2-7x+3$ and $3x^6-3x^4-18x^3+x^2+2x+3$.

160. In some cases the H.C.F. may be found more easily by the application of the following principle:

If A and B denote two expressions having no monomial factors and if m, n, p, q be any four numerical quantities such that $mq-np$ is not equal to zero, then the H.C.F. of A and B is the same as the H.C.F. of $mA+nB$ and $pA+qB$, numerical common factors, if any, being left out. This may be proved as follows:

Let H denote the H.C.F. of A and B, and H' the H.C.F. of $mA+nB$ and $pA+qB$, after removal from them of any numerical common factors that may occur.

Now, since *every* common factor of A and B is a factor of $mA+nB$ and also of $pA+qB$, therefore H is a common factor of $mA+nB$ and $pA+qB$. Hence, H' is either equal to H or is an expression of higher dimensions than H . ... (α)

Again, since $q(mA+nB)-n(pA+qB)=(mq-np)A$,

and $m(pA+qB)-p(mA+nB)=(mq-np)B$,

it is clear that *every* common factor of $mA+nB$ and $pA+qB$ is a factor of $(mq-np)A$, and also of $(mq-np)B$. Hence, as $mq-np$ is only a numerical quantity *every* common factor of those expressions *other than numerical* must be a factor of A as well as of B. Hence, H' is a common factor of A and B and therefore cannot be of higher dimensions than H.

Hence, by (α), $H'=H$, which proves the proposition.

Cor. 1. The H.C.F. of A and B is the same as the H.C.F. of $A+B$ and $A-B$. Here $m=1$, $n=1$, $p=1$ and $q=-1$.

Cor. 2. The H.C.F. of A and B is the same as the H.C.F. of $A\pm B$ and B, here $m=1$, $n=\pm1$, $p=0$ and $q=1$. Similarly it is the same as the H.C.F. of $A\pm B$ and A.

Example 1. Find the H.C.F. of

$$x^4+x^3-5x^2-3x+2 \text{ and } x^4-3x^3+x^2+3x-2$$

Let $\quad A=x^4+x^3-5x^2-3x+2,$

and $\quad B=x^4-3x^3+x^2+3x-2$

Then $\quad A+B=2x^4-2x^3-4x^2=2x^2(x^2-x-2),$

and $\quad A-B=4x^3-6x^2-6x+4=2(2x^3-3x^2-3x+2)$

Hence, by Cor 1 the required H C F is the H C F of $x^2(x^2-x-2)$ and $2x^3-3x^2-3x+2$, and therefore of x^2-x-2 and $2x^3-3x^2-3x+2$

Let $\quad A'=x^2-x-2,$

and $\quad B'=2x^3-3x^2-3x+2$

Then $\quad A'+B'=2x^3-2x^2-4x=2x(x^2-x-2)$

Hence, the required H C F

$=$ the H C F of A' and $A'+B'$ [Cor 2]

$=x^2-x-2$

Example 2. Find the H C F of

$4x^4+11x^3+27x^2+17x+5$ and $3x^4+7x^3+18x^2+7x+5$

Let $\quad A=4x^4+11x^3+27x^2+17x+5,$

and $\quad B=3x^4+7x^3+18x^2+7x+5$

Then $\quad A-B=x^4+4x^3+9x^2+10x$

$=x(x^3+4x^2+9x+10),$

and $\quad 3A-4B=5x^3+9x^2+23x-5$

Hence, the H C F of $x^3+4x^2+9x+10$ and $5x^3+9x^2+23x-5$ is the H C F required

Let $\quad A'=x^3+4x^2+9x+10,$

and $\quad B'=5x^3+9x^2+23x-5$

Then $\quad A'+2B'=11x^3+22x^2+55x=11x(x^2+2x+5),$

and $\quad 5A'-B'=11x^2+22x+55=11(x^2+2x+5)$

Hence, the H C F required is the H C F of $x(x^2+2x+5)$ and x^2+2x+5, and is therefore $=x^2+2x+5$

Example 3. Find the H C F of

$2x^5-11x^2-9$ and $4x^5+11x^4+81$

[C U Entr Paper, 1865]

Let $\quad A=4x^5+11x^4+81,$

and $\quad B=2x^5-11x^2-9$

Then $A-2B=11x^4+22x^2+99=11(x^4+2x^2+9)$,
and $A+9B=22x^5+11x^4-99x^2=11x^2(2x^3+x^2-9)$

Hence, the required H C F is the same as the H C F of x^4+2x^2+9 and $x^2(2x^3+x^2-9)$, and therefore of x^4+2x^2+9 and $2x^3+x^2-9$.

Let $A'=x^4+2x^2+9$,
and $B'=2x^3+x^2-9$

Then $A'+B'=x^4+2x^3+3x^2=x^2(x^2+2x+3)$

Hence, the H C F of

$$\left.\begin{array}{l} 2x^3+x^2-9(=B') \\ \text{and } x^2+2x+3(=C' \text{ say}) \end{array}\right\} \text{is the H C F required}$$

Now, since $B'+3C'=2x^3+4x^2+6x$
$=2x(x^2+2x+3)$,
the H C F reqd $=$ the H C F of C' and $B'+3C'$
$=x^2+2x+3$.

EXERCISE 84.

Find the H.C F of

1. $x^3-3x^2-4x+12$ and $x^3-7x^2+16x-12$

2. $2x^3-17x+12$ and $4x^4-2x^3-34x^2+41x-12$

3. $4x^3+13x^2+19x+4$ and $2x^3+5x^2+5x-4$

4. $3x^3-5x^2+7$ and $6x^4-7x^3-5x^2+14x+7$

5. $6x^4-11x^3+16x^2-22x+8$ and $6x^4-11x^3-8x^2+22x-8$

6. $2x^4+19x^3+20x^2-31x+8$ and $2x^4+7x^3-64x^2+62x-16$

7. $3x^4-7x^3-27x^2-6x+2$ and $3x^4-13x^3-40x^2-9x+3$

8. $5x^4-18x^3-7x^2+12x+3$ and $5x^4-23x^3-9x^2+16x+4$

9. $2x^4-5x^3-17x^2-2x+2$ and $6x^5+23x^4+34x^3+21x^2-2x-2$

10. $6x^5+9x^4-13x^3-4x^2+9x-3$ and $9x^5+12x^4-18x^3-5x^2+12x-4$

11. x^5-x^3+8 and x^5-x^2+4

12. $3x^5+139x^2-44$ and $39x^5+139x^4-16$

161. The H.C.F. of three or more expressions whose factors cannot be easily found.

Let A, B, C stand for any three expressions of which the H C F is to be found

Let G denote the H C F. of A and B, and H that of G and C

Then G being the product of *all* the elementary common factors of A and B, every factor of G is a common factor of A and B, and therefore every common factor of G and C is a common factor of A, B and C

Hence, H also is a common factor of A, B and C Therefore, the H C F required is either H or an expression of higher dimensions than H (β)

But, since every common factor of A and B is a factor of G, *every* common factor of A, B and C is a common factor of G and C Hence, the H C F required is a common factor of G and C, and therefore cannot be of higher dimensions than H

Hence, by (β), the H C F required $= H$

By a similar reasoning it follows that if D be a fourth expression, then the H C F of H and D is the H C F of A, B, C and D

Thus we have the following rule *To find the H C F of any number of expressions A, B, C, D, &c first find the H C F of A and B, then the H.C F of this result and C, and so on, the result obtained last of all is the H C F required*

Example. Find the H C F of $2x^4-7x^3-17x^2+58x-24$, $3x^4+14x^3-11x^2-70x+24$ and $5x^4+9x^3-47x^2-81x+18$

Let us first find the H C F of the first two expressions

Put $\qquad A=2x^4-7x^3-17x^2+58x-24,$

and $\qquad B=3x^4+14x^3-11x^2-70x+24$

Then, $\qquad A+B=5x^4+7x^3-28x^2-12x$

$\qquad\qquad =x(5x^3+7x^2-28x-12),$

and $\qquad -3A+2B=49x^3+29x^2-314x+120$

Hence, the H C F of A and B is the H C F of $5x^3+7x^2-28x-12$ and $49x^3+29x^2-314x+120$

Let $\quad A' = 5x^3 + 7x^2 - 28x - 12,$

and $\quad B' = 49x^3 + 29x^2 - 314x + 120$

Then, $\quad 10A' + B' = 99x^3 + 99x^2 - 594x$

$$= 99x(x^2 + x - 6)$$

Hence, the H C F of A and B is the same as the H C.F of $\left.\begin{array}{l} 5x^3 + 7x^2 - 28x - 12 (= A') \\ \text{and } x^2 + x - 6 (= C' \text{ say}) \end{array}\right\}$

Now, $\quad A' - 2C' = 5x^3 + 5x^2 - 30x = 5x(x^2 + x - 6)$,

$\therefore$ the H C F of A and B = the H C F of C' and

$$A' - 2C' = x^2 + x - 6$$

Hence, the H C F required is the H C F of $x^2 + x - 6$ and $5x^4 + 9x^3 - 47x^2 - 81x + 18$, which can be found as follows

$$\begin{array}{r} x^2 + x - 6 \,\big)\, 5x^4 + 9x^3 - 47x^2 - 81x + 18 \,\big(\, 5x^2 + 4x \\ \underline{5x^4 + 5x^3 - 30x^2 \qquad\qquad\qquad} \\ 4x^3 - 17x^2 - 81x + 18 \\ \underline{4x^3 + 4x^2 - 24x \qquad} \\ -3)\, -21x^2 - 57x + 18 \\ 7x^2 + 19x - 6 \,\big(\, 7 \\ \underline{7x^2 + 7x - 42} \\ 12)\, 12x + 36 \\ x + 3 \end{array}$$

$$\begin{array}{r} x + 3 \,\big)\, x^2 + x - 6 \,\big(\, x - 2 \\ \underline{x^2 + 3x \qquad} \\ -2x - 6 \\ \underline{-2x - 6} \end{array}$$

Thus the required H C F $= x + 3$

EXERCISE 85.

Find the H C F of

1. $2x^3 + 7x^2 - 5x - 4, \quad x^3 + 8x^2 + 11x - 20$ and $2x^3 + 19x^2 + 49x + 20$

2. $2x^4 + 3x^3 + 8x^2 + 15x - 10, \quad 2x^4 - 5x^3 + 12x^2 - 25x + 10$ and $2x^4 - 5x^3 + 10x^2 - 20x + 8$

3. $2x^4 + 7x^3 - 19x^2 - 14x + 30, \quad 2x^4 + 5x^3 - 16x^2 - 10x + 24$ and $2x^4 + 5x^3 - 10x^2 + 5x - 12$

4. $2x^4 - 4x^3 - 69x^2 - 2x - 35, \quad 2x^4 - 6x^3 - 55x^2 - 3x - 28$ and $2x^4 + 18x^3 + 41x^2 + 9x + 20$

5. $3a^3+28a^2b+52ab^2-48b^3$, $3a^3+4a^2b-28ab^2+16b^3$ and $3a^3+10a^2b-44ab^2+24b^3$

6. $6a^3+5a^2b-34ab^2+15b^3$, $6a^3-37a^2b+57ab^2-20b^3$ and $3a^3-8a^2b-31ab^2+60b^3$

7. $3x^4+11x^3-32x^2-44x+80$, $3x^4-x^3-52x^2+124x-80$, $3x^4+2x^3-20x^2-8x+32$ and $3x^4+2x^3-83x^2-50x+200$

8. $6x^5+14x^4-53x^3-37x^2+66x+24$, $6x^5-28x^4+17x^3+54x^2-39x-18$, $6x^5+8x^4-79x^3-36x^2+105x+36$ and $2x^5-2x^4-31x^3+51x^2+42x-72$.

II. Harder L. C. M.

162. L.C.M. of two expressions whose factors are not obvious by inspection.

Let A and B stand for two such expressions, and suppose their H C F is found to be H

Divide A and B by H and let the respective quotients be a and b Then we have

$$\left.\begin{array}{l} A=aH \\ B=bH \end{array}\right\}$$

Hence, since a and b have no common factors, *every* common multiple of A and B must *necessarily* contain $a\times H\times b$ as a factor

Hence, the L C M required $=aHb$

$$\text{But} \quad \left.\begin{array}{r} aHb=a(Hb)=\dfrac{A}{H}\times B \\ \text{or}=(aH)b=A\times\dfrac{B}{H} \end{array}\right\}$$

Hence, the required L C M $=\dfrac{A}{H}\times B$, or $=A\times\dfrac{B}{H}$.

Thus, to find the L C M of any two expressions we have to divide one of them by their H C F and multiply the quotient by the other

Cor. If L denote the L C M of A and B, we have $L\times H=A\times B$, that is, *the product of the L.C M and*

H C F of any two expressions is equal to the product of these expressions

Note *If any two expressions have no common factor, their L C M is evidently equal to their product*

Example. Find the L C M of

$$6x^3+25x^2+16x+7 \text{ and } 6x^3-11x^2-8x-5$$

$$
\begin{array}{r|l|l}
6x^3-11x^2-8x-5 & 6x^3+25x^2+16x+7 & 1 \\
 & \underline{6x^3-11x^2-\ 8x-5} & \\
 & 12)\underline{36x^2+24x+12} & \\
 & 3x^2+\ 2x+\ 1 &
\end{array}
$$

$$
\begin{array}{r|l|l}
3x^2+2x+1 & 6x^3-11x^2-8x-5 & 2x-5 \\
 & \underline{6x^3+\ 4x^2+2x} & \\
 & -15x^2-10x-5 & \\
 & \underline{-15x^2-10x-5} &
\end{array}
$$

Thus the H C F of the given expressions $=3x^2+2x+1$

Hence, the L C M required

$$=\frac{6x^3-11x^2-8x-5}{3x^2+2x+1}(6x^3+25x^2+16x+7)$$

$$=(2x-5)(6x^3+25x^2+16x+7)$$

$$=12x^4+20x^3-93x^2-66x-35$$

EXERCISE 86.

Find the L C M of

1. $3x^3+2x^2-11x+4$ and $3x^3+14x^2+13x-8$

2. $6x^3+17x^2+9x-4$ and $6x^3-7x^2-27x+8$

3. $12x^3-4x^2-25x+12$ and $12x^3-28x^2+7x+12$

4. $9x^3-12x^2-15x+20$ and $15x^3+12x^2-25x-20$

5. $4x^3-10x^2-18x+45$ and $6x^3+8x^2-27x-36$

6. $4x^4+4x^3+7x^2+11x+4$ and $6x^4+7x^3+4x^2+5x+2$

7. $8x^4-6x^3-8x^2+9x-6$ and $16x^4-12x^3+20x^2-9x+6$

8. $4x^4+8x^3+21x^2+18x+27$ and $3x^4+6x^3+17x^2+16x+24$

9. If h be the Highest Common Divisor and l the Lowest Common Multiple of two quantities x and y, and if $h+l=x+y$, prove that $h^3+l^3=x^3+y^3$

[Punjab University Entrance Paper, 1891]

163. L. C. M. of three or more expressions whose factors are not obvious by inspection.

Let A, B, C stand for three such expressions, to find their L C M

Let L denote the L C M of A and B, and M that of L and C

Then evidently *every* common multiple of L and C is a common multiple of A, B, C, (1)

also *every* common multiple of A, B, C is a common multiple of C (2)

From (1), M is a common multiple of A, B, C Hence, either M or an expression of a lower degree than M is the L C M of A, B, C

But an expression of a lower degree than M cannot be the L C M of A, B, C, because from (2) the L C M of A, B C is a common multiple of L and C

Hence, the required L C M $=M$.

Thus, *to find the L C M of any number of expressions A, B, C, D, &c, we have first to find the L C M. of A and B, then the L C M of the result and C, and so on, the last result thus obtained is the L C M required*

Example. Find the L C M of

$$6x^2-11x+3,\ 4x^2-4x-3 \text{ and } 6x^2+25x-9$$

$$\begin{array}{r|r}
6x^2-11x+3\,\big)\,6x^2+25x-9\,\big(\,1 & 3x-1\,\big)\,6x^2-11x+3\,\big(\,2x-3 \\
\underline{6x^2-11x+3} & \underline{6x^2-\ \ 2x\quad} \\
12\underline{)36x-12} & -\ 9x+3 \\
3x-1 & \underline{-\ 9x+3}
\end{array}$$

Thus the H C F. of $6x^2-11x+3$ and $6x^2+25x-9=3x-1$.

Hence, the L C M of these expressions

$$=\frac{6x^2-11x+3}{3x-1}(6x^2+25x-9)$$

$$=(2x-3)(6x^2+25x-9)$$

$$=12x^3+32x^2-93x+27$$

Now to find the L C M of this expression and $4x^2-4x-3$

$$\begin{array}{r|l|l}
4x^2-4x-3 & 12x^3+32x^2-93x+27 & 3x+11 \\
 & \underline{12x^3-12x^2-\ \ 9x} & \\
 & \quad 44x^2-84x+27 & \\
 & \quad \underline{44x^2-44x-33} & \\
 & -20)\ \underline{-40x+60} & \\
 & \qquad\quad 2x-3 &
\end{array}$$

$$\begin{array}{r|l|l}
2x-3 & 4x^2-4x-3 & 2x+1 \\
 & \underline{4x^2-6x} & \\
 & \quad 2x-3 & \\
 & \quad \underline{2x-3} &
\end{array}$$

Thus the H C F of the expressions considered $=2x-3$

Hence, their L C M

$$=\frac{4x^2-4x-3}{2x-3}(12x^3+32x^2-93x+27)$$
$$=(2x+1)(12x^3+32x^2-93x+27)$$
$$=24x^4+76x^3-154x^2-39x+27$$

EXERCISE 87.

Find the L C M. of

1. $3x^2-10x-8$, $4x^2-20x+9$ and $6x^2+x-2$

2. $3x^2-23x-8$, $6x^2-7x-3$ and $2x^2-11x+12$

3. $6x^2-19x+10$, $12x^2-11x+2$ and $8x^2+10x-3$

4. $2x^4+4x^3+x^2+6x-3$, $4x^4+8x^3-7x^2-6x+3$ and $8x^4+4x^3-2x^2-3x-3$

CHAPTER XXV

HARDER FRACTIONS

164. In this Chapter we shall consider fractions of a harder type than those treated of in Chapter XVI

I. Reduction of Fractions.

165. A fraction is said to be reduced to its lowest terms, when its numerator and denominator have no common factor In all cases where the numerator and denominator can be

factorised by inspection, the reduction is effected by simply removing the common factors Otherwise, divide both the numerator and the denominator by their highest common factor.

Example 1. Reduce to its lowest terms

$$\frac{a^3+b^3+c^3-3abc}{a^2(b+c)+b^2(c+a)+c^2(a+b)+3abc}.$$

$$\text{The fraction}=\frac{(a+b+c)(a^2+b^2+c^2-bc-ca-ab)}{(a+b+c)(bc+ca+ab)}$$

$$=\frac{a^2+b^2+c^2-bc-ca-ab}{bc+ca+ab}.$$

Example 2. Simplify $\dfrac{8(x+y+z)^3-(y+z)^3-(z+x)^3-(x+y)^3}{3(2x+y+z)(x+2y+z)(x+y+2z)}$.

$$\text{The fraction}=\frac{3(2x+y+z)(x+2y+z)(x+y+2z)}{3(2x+y+z)(x+2y+z)(x+y+2z)}$$

[Ex 1, Art 132]

$$=1$$

Example 3. Reduce to its lowest terms

$$\frac{3x^3-27ax^2+78a^2x-72a^3}{2x^3+10ax^2-4a^2x-48a^3}.$$

[C U. Entr Paper 1889]

The numerator $=3(x^3-9ax^2+26a^2x-24a^3)$

The denominator $=2(x^3+5ax^2-2a^2x-24a^3)$

Now to find their H C F

$$\begin{array}{r}
x^3+5ax^2-\ 2a^2x-24a^3 \\
x^3-9ax^2+26a^2x-24a^3 \\
\hline
14ax)\,14ax^2-28a^2x \\
x\ -\ 2a
\end{array}$$

$$\begin{array}{l|l|l}
x-2a & x^3-9ax^2+26a^2x-24a^3 & x^2-7ax+12a^2 \\
 & x^3-2ax^2 & \\
\hline
 & -7ax^2+26a^2x-24a^3 & \\
 & -7ax^2+14a^2x & \\
\hline
 & \quad 12a^2x-24a^3 & \\
 & \quad 12a^2x-24a^3 & \\
\hline
\end{array}$$

Thus the H C F required $=x-2a$

Hence, the required result

$$=\frac{3(x^3-9ax^2+26a^2x-24a^3)-(x-2a)}{2(x^3+5ax^2-2a^2x-24a^3)-(x-2a)}$$

$$=\frac{3(x^2-7ax+12a^2)}{2(x^2+7ax+12a^2)}$$

Example 4. Reduce $\dfrac{2x^4-x^3-9x^2+13x-5}{7x^3-19x^2+17x-5}$ to its lowest terms [C U Entr Paper, 1870]

The H C F of the numerator and the denominator of the given fraction can be found as follows

$$\begin{array}{rl}
 & 2x^4-x^3-\ 9x^2+13x-5 \quad \text{[See Cor 2, Art 160]} \\
 & \underline{7x^3-19x^2+17x-5} \\
2x) & \underline{2x^4-8x^3+10x^2-\ 4x} \\
 & x^3-\ 4x^2+\ 5x-2
\end{array}$$

$$\begin{array}{r|l|l}
x^3-4x^2+5x-2 & 7x^3-19x^2+17x-\ 5 & 7 \\
 & \underline{7x^3-28x^2+35x-14} & \\
 & 9)\underline{9x^2-18x+\ 9} & \\
 & x^2-\ 2x+\ 1 &
\end{array}$$

$$\begin{array}{r|l|l}
x^2-2x+1 & x^3-4x^2+5x-2 & x-2 \\
 & \underline{x^3-2x^2+\ x} & \\
 & -2x^2+4x-2 & \\
 & \underline{-2x^2+4x-2} &
\end{array}$$

Thus the H C F required $=x^2-2x+1$

Hence, the required result

$$=\frac{(2x^4-x^3-9x^2+13x-5)-(x^2-2x+1)}{(7x^3-19x^2+17x-5)-(x^2-2x+1)}$$

$$=\frac{2x^2+3x-5}{7x-5}.$$

EXERCISE 88.

Reduce to the lowest terms .

1. $\dfrac{x^3+4x^2+x-6}{x^2+x-2}$.
2. $\dfrac{x^3-7x+6}{x^3+2x^2-13x+10}$.
3. $\dfrac{a^3+2a^2b-2ab^2+3b^3}{a^3-5a^2b+5ab^2-4b^3}$
4. $\dfrac{x^4+(2b^2-a^2)x^2+b^4}{x^4+2ax^3+a^2x^2-b^4}$.
5. $\dfrac{3x^3+4x^2y-7xy^2+2y^3}{2x^3+9x^2y+8xy^2-5y^3}$.
6. $\dfrac{1+3x-x^3-3x^4}{1-x+2x^2+x^3+3x^4}$

7. $\dfrac{x^4-x^3-x+1}{x^4-2x^3-x^2-2x+1}$. **8.** $\dfrac{x^4+x^2+25}{x^4-9x^2+30x-25}$.

9. $\dfrac{2x^3+3ax^2+5a^2x-21a^3}{4x^3-12ax^2+19a^2x-15a^3}$.

10. $\dfrac{2x^4+x^3-3x^2+2x+3}{3x^4+x^3-4x^2+3x+4}$. **11.** $\dfrac{9x^3-7a^2x-2a^3}{9x^3+6ax^2-5a^2x-2a^3}$.

12. $\dfrac{2a^3-16a^2b+44ab^2-42b^3}{3a^3+6a^2b-24ab^2-63b^3}$.

13. $\dfrac{9x^4+30x^3+12x^2-6x-45}{8x^4+28x^3+16x^2-4x-48}$.

14. $\dfrac{6a^6-9a^5b+a^4b^2+3a^3b^3-a^2b^4}{4a^5-6a^4b+3a^2b^3-ab^4}$

15. $\dfrac{24x^5+16x^4y-28x^3y^2-24x^2y^3-12xy^4}{45x^4y+30x^3y^2-15x^2y^3-20xy^4-10y^5}$.

16. $\dfrac{(b+c)^3(b-c)+(c+a)^3(c-a)+(a+b)^3(a-b)}{(b+c)^2(b-c)+(c+a)^2(c-a)+(a+b)^2(a-b)}$.

17. $\dfrac{(1-x^2)(1-y^2)(1-z^2)-(yz+x)(zx+y)(xy+z)}{1-x^2-y^2-z^2-2xyz}$.

18. $\dfrac{(x+y-2z)^3+(y+z-2x)^3+(z+x-2y)^3}{12(x+y-2z)(y+z)(y+z-2x)}$.

19. $\dfrac{(y-z)^2+(z-x)^2+(x-y)^2}{(x-y)(x-z)+(y-z)(y-x)+(z-x)(z-y)}$.

20. $\dfrac{7x^3-2x^2y-63xy^2-18y^3}{5x^4-3x^3y-43x^2y^2+27xy^3-18y^4}$. [P U. 1912]

II. Addition and Subtraction of Fractions.

166. We know $\dfrac{p}{a}+\dfrac{q}{a}+\dfrac{r}{a}+\dots=\dfrac{p+q+r+\dots}{a}$, so that the sum of any number of fractions which have a common denominator is a fraction whose denominator is the same and whose numerator is the sum of the numerators of the given fractions

Hence to obtain the sum of any number of fractions which have not the same denominator we must first of all reduce them to equivalent fractions having a common denominator by the method of Art 108, and then proceed as above

Example 1. Simplify $\dfrac{a^2}{(x-a)^n}+\dfrac{2a}{(x-a)^{n-1}}+\dfrac{1}{(x-a)^{n-2}}$.

[M M 1865]

$$\text{The expression}=\frac{a^2}{(x-a)^n}+\frac{2a(x-a)}{(x-a)^n}+\frac{(x-a)^2}{(x-a)^n}$$
$$=\frac{a^2+2a(x-a)+(x-a)^2}{(x-a)^n}$$
$$=\frac{\{a+(x-a)\}^2}{(x-a)^n}$$
$$=\frac{x^2}{(x-a)^n}.$$

Example 2. Simplify $\dfrac{1}{x-2}-\dfrac{1}{x+2}-\dfrac{4}{x^2+4}+\dfrac{32}{x^4+16}$.

To simplify examples like this, we combine two suitable terms, then the result thus obtained with a third, and so on

$$\text{Thus, we have } \frac{1}{x-2}-\frac{1}{x+2}=\frac{(x+2)-(x-2)}{x^2-4}=\frac{4}{x^2-4};$$
$$\frac{4}{x^2-4}-\frac{4}{x^2+4}=\frac{4(x^2+4)-4(x^2-4)}{x^4-16}=\frac{32}{x^4-16}.$$
$$\text{Lastly,}\quad \frac{32}{x^4-16}+\frac{32}{x^4+16}=\frac{32(x^4+16)+32(x^4-16)}{x^8-256}$$
$$=\frac{64x^4}{x^8-256},$$ which is the reqd result

Example 3. Simplify $\dfrac{1}{a+b}-\dfrac{1}{a+2b}-\dfrac{1}{a+3b}+\dfrac{1}{a+4b}$.

Instead of simplifying all the terms together, it is convenient to combine them by groups

$$\text{Thus, the given exp}=\left\{\frac{1}{a+b}-\frac{1}{a+2b}\right\}-\left\{\frac{1}{a+3b}-\frac{1}{a+4b}\right\}.$$

$$\text{Now, we have } \frac{1}{a+b}-\frac{1}{a+2b}=\frac{(a+2b)-(a+b)}{(a+b)(a+2b)}$$
$$=\frac{b}{(a-b)(a+2b)};$$
$$\text{and}\quad \frac{1}{a+3b}-\frac{1}{a+4b}=\frac{(a+4b)-(a+3b)}{(a+3b)(a+4b)}$$
$$=\frac{b}{(a+3b)(a+4b)}.$$

Lastly, $\frac{b}{(a+b)(a+2b)}-\frac{b}{(a+3b)(a+4b)}$

$$=\frac{b(a+3b)(a+4b)-b(a+b)(a+2b)}{(a+b)(a+2b)(a+3b)(a+4b)},$$

of which the numerator $=b(a^2+7ab+12b^2)-b(a^2+3ab+2b^2)$

$$=b(4ab+10b^2)=2b^2(2a+5b)$$

Hence the reqd result $=\frac{2b^2(2a+5b)}{(a+b)(a+2b)(a+3b)(a+4b)}$.

Example 4. Simplify $\frac{x+3}{x^2-3x+2}+\frac{x+2}{x^2-4x+3}+\frac{x+1}{x^2-5x+6}$.

[P U 1904]

The first denominator $=x^2-3x+2=(x-1)(x-2)$
The second denominator $=x^2-4x+3=(x-3)(x-1)$
The third denominator $=x^2-5x+6=(x-2)(x-3)$
The L C M of the denominators $=(x-1)(x-2)(x-3)$

Hence, the given expression

$$=\frac{x+3}{(x-1)(x-2)}+\frac{x+2}{(x-3)(x-1)}+\frac{x+1}{(x-2)(x-3)}$$

$$=\frac{(x+3)(x-3)+(x+2)(x-2)+(x+1)(x-1)}{(x-1)(x-2)(x-3)}$$

$$=\frac{x^2-9+x^2-4+x^2-1}{(x-1)(x-2)(x-3)}=\frac{3x^2-14}{(x-1)(x-2)(x-3)}.$$

Example 5. Simplify

$$\frac{x-y}{(a+x)(a+y)}+\frac{y-z}{(a+y)(a+z)}+\frac{z-x}{(a+z)(a+x)}.$$ [A U 1915]

The L C M of the denominators $=(a+x)(a+y)(a+z)$

The given expression

$$=\frac{(a+z)(x-y)+(a+x)(y-z)+(a+y)(z-x)}{(a+x)(a+y)(a+z)}.$$

The numerator $=a\{(x-y)+(y-z)+(z-x)\}$
$+z(x-y)+x(y-z)+y(z-x)$
$=0$ [simplifying]

The given expression

$$=\frac{0}{(a+x)(a+y)(a+z)}=0$$

Otherwise Since

$$\frac{1}{a+y}-\frac{1}{a+x}=\frac{(a+x)-(a+y)}{(a+x)(a+y)}=\frac{x-y}{(a+x)(a+y)},$$

$$\frac{1}{a+z}-\frac{1}{a+y}=\frac{(a+y)-(a+z)}{(a+y)(a+z)}=\frac{y-z}{(a+y)(a+z)},$$

and
$$\frac{1}{a+x}-\frac{1}{a+z}=\frac{(a+z)-(a+x)}{(a+z)(a+x)}=\frac{z-x}{(a+z)(a+x)}.$$

We have the given expression

$$=\frac{1}{a+y}-\frac{1}{a+x}+\frac{1}{a+z}-\frac{1}{a+y}+\frac{1}{a+x}-\frac{1}{a+z}=0$$

Example 6. Simplify $\frac{a}{a+b}+\frac{2a^2}{a^2+b^2}+\frac{4a^2b^2}{a^4-b^4}$.

Such expressions are easily simplified by adding and subtracting a suitable fraction Thus adding and subtracting $\frac{a}{a-b}$, the given expression

$$=\frac{a}{a-b}+\frac{a}{a+b}+\frac{2a^2}{a^2+b^2}+\frac{4a^2b^2}{a^4-b^4}-\frac{a}{a-b}.$$

Now,
$$\frac{a}{a-b}+\frac{a}{a+b}=\frac{a(a+b)+(a-b)a}{a^2-b^2}=\frac{2a^2}{a^2-b^2}.$$

Again,
$$\frac{2a^2}{a^2-b^2}+\frac{2a^2}{a^2+b^2}=\frac{2a^2(a^2+b^2)+2a^2(a^2-b^2)}{a^4-b^4}=\frac{4a^4}{a^4-b^4},$$

and
$$\frac{4a^4}{a^4-b^4}+\frac{4a^2b^2}{a^4-b^4}=\frac{4a^4+4a^2b^2}{a^4-b^4}$$

$$=\frac{4a^2(a^2+b^2)}{a^4-b^4}=\frac{4a^2}{a^2-b^2}.$$

The given expression

$$=\frac{4a^2}{a^2-b^2}-\frac{a}{a-b}=\frac{4a^2-a(a+b)}{a^2-b^2}=\frac{3a^2-ab}{a^2-b^2}=\frac{a(3a-b)}{a^2-b^2},$$

EXERCISE 89.

Simplify:

1. $\frac{x}{3x-y}+\frac{x}{3x+y}+\frac{6x^2}{9x^2+y^2}$.

2. $\frac{1}{x-3a}-\frac{1}{2x+6a}-\frac{x-9a}{2x^2+18a^2}$. **3.** $\frac{(a^2+b^2)^2}{ab(a-b)^2}-\frac{a}{b}-\frac{b}{a}-2$

4. $\frac{1}{x-1}-\frac{1}{x+1}+\frac{1}{x-2}-\frac{1}{x+2}$.

5. $\frac{1}{x-a}-\frac{2}{2x+a}+\frac{1}{x+a}-\frac{2}{2x-a}$.

6. $\frac{3}{a-x}-\frac{1}{x+3a}+\frac{3}{a+x}+\frac{1}{x-3a}$.

7. $\frac{2}{x-1}-\frac{x}{x^2+1}-\frac{1}{x+1}+\frac{3}{1-x^2}$.

8. $\frac{a-c}{(a-b)(x-a)}+\frac{b-c}{(b-a)(x-b)}$.

9. $\frac{1}{x^2-3x+2}+\frac{1}{x^2-5x+6}+\frac{2}{x^2-8x+15}$.

10. $\frac{1}{x^2+5ax+4a^2}+\frac{1}{x^2+11ax+28a^2}+\frac{2}{x^2+20ax+91a^2}$.

11. $\frac{1}{x^2+3x+2}+\frac{2x}{x^2+4x+3}+\frac{1}{x^2+5x+6}$.

12. $\frac{1}{1-x+x^2}-\frac{1}{1+x+x^2}-\frac{2x}{1+x^2+x^4}$.

13. $\frac{1}{1+x+x^2}-\frac{1}{1-x+x^2}+\frac{2x}{1-x^2+x^4}$.

14. $\frac{1}{x-2}-\frac{x-2}{x^2+2x+4}+\frac{6x}{x^3+8}$.

15. $\frac{1}{2x^2-6ax+9a^2}-\frac{1}{2x^2+6ax+9a^2}+\frac{12ax}{4x^4-81a^4}$.

16. $\frac{1}{(x+a)(x+2a)}+\frac{1}{(x+2a)(x+3a)}+\frac{1}{(x+3a)(x+4a)}$.

17. $\frac{a-b}{(x+a)(x+b)}+\frac{b-c}{(x+b)(x+c)}+\frac{c-d}{(x+c)(x+d)}$.

18. $\frac{1}{a^2-3a+2}+\frac{2}{a^2-5a+6}+\frac{3}{a^2-4a+3}$.

19. $\frac{1}{(x+1)^2(x+2)^2}-\frac{1}{(x+1)^2}+\frac{2}{x+1}-\frac{2}{x+2}$. [A U 1912]

20. $\frac{2(x-3)}{(x-4)(x-5)}-\frac{x-1}{(x-3)(x-4)}-\frac{x-2}{(x-5)(x-3)}$. [A U 1911]

21. $\frac{1}{1+a}+\frac{2}{1+a^2}+\frac{4}{1+a^4}+\frac{8}{1+a^8}-\frac{16}{1-a^{16}}$.

22. $\left(\sqrt{\frac{a+x}{x}}-\sqrt{\frac{x}{a+x}}\right)^2-\left(\sqrt{\frac{x}{a}}-\sqrt{\frac{a}{x}}\right)^2+\frac{x^2}{a(a+x)}$.

[B U 1876]

23. $\dfrac{a}{(a-b)(a-c)}+\dfrac{b}{(b-a)(b-c)}+\dfrac{c}{(c-a)(c-b)}$.

24. $\dfrac{1}{x^2-5x+6}-\dfrac{2}{x^2-4x+3}+\dfrac{1}{x^2-3x+2}$.

25. $1+\dfrac{a}{x-a}+\dfrac{bx}{(x-a)(x-b)}+\dfrac{cx^2}{(x-a)(x-b)(x-c)}$
$$+\frac{dx^3}{(x-a)(x-b)(x-c)(x-d)}.$$

III. Complex and Continued Fractions.

167. Complex Fractions. A fraction which contains a fraction in its numerator or in its denominator or in both, is called a **complex fraction.**

Thus, $\dfrac{\frac{x}{y}}{z}$, $\dfrac{x}{\frac{y}{z}}$, $\dfrac{\frac{x}{y}}{\frac{a}{b}}$ are complex fractions, which are therefore, merely divisions of fractions

We have already considered simplifications of such fractions in Art 111

168. Continued Fractions. Fractions of the type

$x+\cfrac{a}{b+\cfrac{c}{d+\cfrac{e}{f+\text{etc}}}}$ are called **continued fractions.**

To simplify such fractions, begin from the bottom and proceed upwards step by step as in Arithmetic

Example 1. Simplify $-1+\cfrac{a}{2(a+b)-\cfrac{a+b}{1-\cfrac{b}{a+b}}}$.

Since, $1-\dfrac{b}{a+b}=\dfrac{a+b-b}{a+b}=\dfrac{a}{a+b}$, we have, by simplifying from the bottom, the given expresssion

$$=-1+\cfrac{a}{2(a+b)-\cfrac{a+b}{\cfrac{a}{a+b}}}$$

$$= -1 + \cfrac{a}{2(a+b) - \cfrac{(a+b)^2}{a}}$$

$$= -1 + \cfrac{a}{\cfrac{2a^2+2ab-(a^2+2ab+b^2)}{a}}$$

$$= -1 + \frac{a^2}{a^2-b^2} = \frac{-a^2+b^2+a^2}{a^2-b^2} = \frac{b^2}{a^2-b^2}.$$

Example 2. Simplify $\cfrac{1}{1+\cfrac{1}{1+\cfrac{1}{1+\cfrac{1}{x}}}}$. [A U 1912]

Proceeding from the bottom, the given expression

$$= \cfrac{1}{1+\cfrac{1}{1+\cfrac{1}{\cfrac{1+x}{x}}}} = \cfrac{1}{1+\cfrac{1}{1+\cfrac{x}{1+x}}} = \cfrac{1}{1+\cfrac{1}{\cfrac{1+x+x}{1+x}}}$$

$$= \cfrac{1}{1+\cfrac{1+x}{1+2x}} = \cfrac{1}{\cfrac{1+2x+1+x}{1+2x}} = \frac{1+2x}{2+3x}.$$

Example 3. Solve $\cfrac{1}{1+\cfrac{1}{1+\cfrac{1}{1+\cfrac{1}{x}}}} = \frac{3}{4}$

By example 2 above, we have the left-hand side

$$= \frac{1+2x}{2+3x} = \frac{3}{4};$$

or, $3(2+3x) = 4(1+2x)$,

i e, $6+9x = 4+8x$,

or, $9x - 8x = 4 - 6$, [transposing]

or, $x = -2$

EXERCISE 90.

Simplify

1. $\dfrac{\left(\frac{y}{z}-\frac{z}{y}\right)\left(\frac{z}{x}-\frac{x}{z}\right)\left(\frac{x}{y}-\frac{y}{x}\right)}{\left(\frac{1}{y^2}-\frac{1}{z^2}\right)\left(\frac{1}{z^2}-\frac{1}{x^2}\right)\left(\frac{1}{x^2}-\frac{1}{y^2}\right)}$. [B U. 1926]

2. $\dfrac{\dfrac{a}{a-b}+\dfrac{b}{b-c}+\dfrac{c}{c-a}}{\dfrac{a+b}{a-b}+\dfrac{b+c}{b-c}+\dfrac{c+a}{c-a}+3}$. 3. $\dfrac{\dfrac{a^2}{x-a}+\dfrac{b^2}{x-b}+\dfrac{c^2}{x-c}}{\dfrac{ax}{x-a}+\dfrac{bx}{x-b}+\dfrac{cx}{x-c}-(a+b+c)}$.

4. $\dfrac{\dfrac{1}{a}+\dfrac{1}{b+c}}{\dfrac{1}{a}-\dfrac{1}{b+c}}\times\left\{1+\dfrac{b^2+c^2-a^2}{2bc}\right\}$. [C U 1921]

5. $\dfrac{1}{1+\dfrac{a}{1+a+\dfrac{2a^2}{1-a}}}$. 6. $\dfrac{1}{1+\dfrac{1}{a+x}}+\dfrac{1}{1-\dfrac{1}{a-x}}+\dfrac{2}{1+\dfrac{1}{a^2-x^2}}$.

[C U 1870]

7. $\dfrac{\dfrac{a}{a-x}+\dfrac{b}{b-x}+\dfrac{c}{c-x}}{\dfrac{3}{x}-\dfrac{1}{x-a}-\dfrac{1}{x-b}-\dfrac{1}{x-c}}$.

8. $\dfrac{\dfrac{a^3}{b^3}-\dfrac{b^3}{a^3}}{\left(\dfrac{a}{b}-\dfrac{b}{a}\right)\left(\dfrac{a}{b}+\dfrac{b}{a}-1\right)}\times\dfrac{\dfrac{1}{b}-\dfrac{1}{a}}{\dfrac{1}{a^2}+\dfrac{1}{b^2}+\dfrac{1}{ab}}$.

9. $\dfrac{\dfrac{1}{2(x-1)}-\dfrac{1}{x-2}+\dfrac{1}{2(x-3)}}{\dfrac{1}{(x-2)(x-1)}+\dfrac{1}{(x-1)(x-3)}+\dfrac{1}{(x-2)(x-3)}}$.

10. $\dfrac{\dfrac{x+y}{x-y}+\dfrac{x^2+y^2}{x^2-y^2}}{\dfrac{x-y}{x+y}-\dfrac{x^3-y^3}{x^3+y^3}}$. 11. $\dfrac{a}{b+\dfrac{c}{d+\dfrac{e}{f}}}$. 12. $\dfrac{x}{x-\dfrac{x-1}{1-\dfrac{1}{x+1}}}$.

13. $a^2+\dfrac{b^4}{a^2-\dfrac{a^3+b^3}{a+\dfrac{b^2}{a-b}}}$. 14. $\dfrac{m}{m^2-\dfrac{m^3-1}{m+\dfrac{1}{m+1}}}$.

15. $\dfrac{\dfrac{x^2-2xy+y^2}{x+y}}{\dfrac{x+y}{x+y-\dfrac{(x-y)^2}{x+y}}-1}$. 16. $\dfrac{x^2(x+2)}{4x+8+\dfrac{2x^4-32}{x+2+\dfrac{(x-2)(x-2)}{x+2}}}$.

Solve

17. $\dfrac{1}{x+\dfrac{1}{1+\dfrac{x+1}{2-x}}}=\frac{4}{3}$. **18.** $\dfrac{2x}{1+\dfrac{1}{1+\dfrac{x}{1-x}}}=1$

19. $1+\dfrac{1}{2+\dfrac{1}{3+\dfrac{1}{x}}}=\frac{13}{9}$. **20.** $\dfrac{a}{a+\dfrac{a^2}{a+\dfrac{a^2}{x}}}=\frac{2}{3}$.

169. Fractions involving Cyclic Order. Certain fractions are easily simplified when the cyclic order of letters is maintained

Example. Simplify $\dfrac{bc}{(a-b)(a-c)}+\dfrac{ca}{(b-c)(b-a)}+\dfrac{ab}{(c-a)(c-b)}$.

Considering the denominator, we see that the factor $a-c$ is not in cyclic order

Since $a-c=-(c-a)$, $(a-b)(a-c)=-(a-b)(c-a)$

Hence, the first fraction $=-\dfrac{bc}{(a-b)(c-a)}$.

Similarly, the second fraction $=-\dfrac{ca}{(b-c)(a-b)}$;

and the third fraction $=-\dfrac{ab}{(c-a)(b-c)}$.

The L C M of the denominators $=(b-c)(c-a)(a-b)$

The given expression

$$=-\left[\frac{bc}{(a-b)(c-a)}+\frac{ca}{(a-b)(b-c)}+\frac{ab}{(c-a)(b-c)}\right]$$

$$=-\frac{bc(b-c)+ca(c-a)+ab(a-b)}{(b-c)(c-a)(a-b)}$$

$$=\frac{(b-c)(c-a)(a-b)}{(b-c)(c-a)(a-b)}=1$$

170. Important Results in Cyclic Order. The following results can be easily verified and are very useful in simplifying many harder examples in fractions involving cyclic order

If $\dfrac{1}{(a-b)(a-c)}=X$, $\dfrac{1}{(b-c)(b-a)}=Y$ and $\dfrac{1}{(c-a)(c-b)}=Z$,

then (i) $X+Y+Z=0$,

(ii) $aX+bY+cZ=0$,

(iii) $a^2X+b^2Y+c^2Z=1$,
(iv) $bcX+caY+abZ=1$,
(v) $a^3X+b^3Y+c^3Z=a+b+c$,
(vi) $a^4X+b^4Y+c^4Z=a^2+b^2+c^2+bc+ca+ab$

Example 1. Simplify $\dfrac{a^2-bc}{(a-b)(a-c)}+\dfrac{b^2-ca}{(b-c)(b-a)}+\dfrac{c^2-ab}{(c-a)(c-b)}$.

The given expression $=(a^2-bc)X+(b^2-ca)Y+(c^2-ab)Z$,
[adopting above notations]
$=a^2X+b^2Y+c^2Z-(bcX+caY+abZ)$
$=1-1$ [Results (iii) and (iv)]
$=0$

Example 2. Simplify

$$\frac{pa^3+qa^2bc+ra}{(a-b)(a-c)}+\frac{pb^3+qab^2c+rb}{(b-c)(b-a)}+\frac{pc^3+qabc^2+rc}{(c-a)(c-b)}.$$

The given expression

$=(pa^3+qa^2bc+ra)X+(pb^3+qab^2c+rb)Y+(pc^3+qabc^2+rc)Z$,
[adopting above notations]

$=p(a^3X+b^3Y+c^3Z)+qabc(aX+bY+cZ)+r(aX+bY+cZ)$
$=p(a+b+c)+qabc\ 0+r\ 0=p(a+b+c)$

Example 3. Show that

$$\frac{1}{(l-m)(l-n)(x+l)}+\frac{1}{(m-n)(m-l)(x+m)}+\frac{1}{(n-l)(n-m)(x+n)}$$
$$=\frac{1}{(x+l)(x+m)(x+n)}.$$

Putting a for $x+l$, b for $x+m$, c for $x+n$, we have

$a-b=l-m$,
$a-c=l-n$
$b-c=m-n$, etc

The given expression

$$=\frac{1}{a(a-b)(a-c)}+\frac{1}{b(b-a)(b-c)}+\frac{1}{c(c-a)(c-b)}$$
$$=\frac{1}{abc}\left[\frac{bc}{(a-b)(a-c)}+\frac{ca}{(b-a)(b-c)}+\frac{ab}{(c-a)(c-b)}\right]$$
$$=\frac{1}{abc}(bcX+caY+abZ)$$
$$=\frac{1}{abc}=\frac{1}{(x+l)(x+m)(x+n)}.$$

[restoring values of a, b, c]

171. Fractional Identities: Miscellaneous Examples.

Example 1. Show that

$$\frac{x}{x^2+a^2}=\frac{1}{x}-\frac{a^2}{x^3}+\frac{a^4}{x^5}-\frac{a^6}{x^7}+\frac{a^8}{x^7(x^2+a^2)}.$$

Let us divide x by x^2+a^2.

$$x^2+a^2\,\big)\,x\,\left(\frac{1}{x}-\frac{a^2}{x^3}+\frac{a^4}{x^5}-\frac{a^6}{x^7}\right.$$

$$\underline{x+\frac{a^2}{x}}$$

$$-\frac{a^2}{x}$$

$$\underline{-\frac{a^2}{x}-\frac{a^4}{x^3}}$$

$$\frac{a^4}{x^3}$$

$$\underline{\frac{a^4}{x^3}+\frac{a^6}{x^5}}$$

$$-\frac{a^6}{x^5}$$

$$\underline{-\frac{a^6}{x^5}-\frac{a^8}{x^7}}$$

$$\frac{a^8}{x^7}$$

Hence, proceeding no further with the division, we have

$$\frac{x}{x^2+a^2}=\frac{1}{x}-\frac{a^2}{x^3}+\frac{a^4}{x^5}-\frac{a^6}{x^7}+\frac{\left(\frac{a^8}{x^7}\right)}{x^2+a^2}$$

$$=\frac{1}{x}-\frac{a^2}{x^3}+\frac{a^4}{x^5}-\frac{a^6}{x^7}+\frac{a^8}{x^7(x^2+a^2)}.$$

Example 2. Find the value of

$\frac{x+2a}{x-2a}+\frac{x+2b}{x-2b}$, when $x=\frac{4ab}{a+b}$. [C U Entr Paper, 1865]

The given expression

$$=\left(\frac{x+2a}{x-2a}-1\right)+\left(\frac{x+2b}{x-2b}-1\right)+2$$

$$=\frac{4a}{x-2a}+\frac{4b}{x-2b}+2$$

$$=\frac{4}{(x-2a)(x-2b)}\left\{a\left(x-2b\right)+b\left(x-2a\right)\right\}+2$$

$$=\frac{4}{(x-2a)(x-2b)}\left\{\left(a+b\right)x-4ab\right\}+2$$

$$=0+2 \qquad [\because \ (a+b)x=4ab]$$

$$=2.$$

Example 3. If $\frac{1}{a}+\frac{1}{b}+\frac{1}{c}=\frac{1}{a+b+c}$, show that

$$\frac{1}{a^7}+\frac{1}{b^7}+\frac{1}{c^7}=\frac{a}{(a+b+c)^7}=\frac{1}{a^7+b^7+c^7}.$$

Since $\quad \frac{1}{a+b+c}=\frac{1}{a}+\frac{1}{b}+\frac{1}{c}=\frac{bc+ca+ab}{abc};$

$$(a+b+c)(bc+ca+ab)=abc,$$

or, $(a+b+c)(bc+ca+ab)-abc=0,$

or, $\quad (b+c)(c+a)(a+b)=0$

Any one of these factors, say $b+c=0$

Hence, $b=-c, \qquad b^7=(-c)^7=-c^7,$

or, $\quad b^7+c^7=0$

Also, since $b=-c, \qquad \frac{1}{b}=-\frac{1}{c};$

$$\frac{1}{b^7}=\left(-\frac{1}{c}\right)^7=-\frac{1}{c^7}.$$

Hence, $\quad \frac{1}{a^7}+\frac{1}{b^7}+\frac{1}{c^7}=\frac{1}{a^7}-\frac{1}{c^7}+\frac{1}{c^7}=\frac{1}{a^7}=\frac{1}{(a+b+c)^7}.$

$$[\because \ b+c=0]$$

Similarly, $\frac{1}{a^7}+\frac{1}{b^7}+\frac{1}{c^7}=\frac{1}{a^7}=\frac{1}{a^7+b^7+c^7} \qquad [\quad b^7+c^7=0]$

Hence, the identity is established

Example 4. Reduce to its simplest form

$$\frac{x^2-(y-z)^2}{(x+z)^2-y^2}+\frac{y^2-(x-z)^2}{(x+y)^2-z^2}+\frac{z^2-(x-y)^2}{(y+z)^2-x^2} \quad [\text{C U } 1866]$$

We have, 1st fraction $=\frac{\{x+(y-z)\}\{x-(y-z)\}}{\{(x+z)+y\}\{(x+z)-y\}}$

$$=\frac{(x+y-z)(x-y+z)}{(x+z+y)(x+z-y)}=\frac{x+y-z}{x+y+z}.$$

Similarly, 2nd fraction $=\frac{(y+x-z)(y-x+z)}{(x+y+z)(x+y-z)}=\frac{y-x+z}{x+y+z},$

and 3rd fraction $=\dfrac{(z+x-y)(z-x+y)}{(y+z+x)(y+z-x)}=\dfrac{z+x-y}{x+y+z}.$

Hence, the given exp $=\dfrac{(x+y-z)+(y-x+z)+(z+x-y)}{x+y+z}$

$$=\frac{x+y+z}{x+y+z}=1.$$

Example 5. If $x+y+z=xyz$, prove that

$$\frac{y+z}{1-yz}+\frac{z+x}{1-zx}+\frac{x+y}{1-xy}=\frac{y+z}{1-yz}\cdot\frac{z+x}{1-zx}\cdot\frac{x+y}{1-xy}.$$

Since $x+y+z=xyz$, we have

$$y+z=xyz-x=x(yz-1).$$

Hence, $\dfrac{y+z}{1-yz}=\dfrac{x(yz-1)}{1-yz}=-x$

Similarly, $\dfrac{z+x}{1-zx}=-y$ and $\dfrac{x+y}{1-xy}=-z$

The left side $=\dfrac{y+z}{1-yz}+\dfrac{z+x}{1-zx}+\dfrac{x+y}{1-xy}$

$$=-x-y-z=-(x+y+z)=-xyz$$

$$=(-x)(-y)(-z)$$

$$=\frac{y+z}{1-yz}\cdot\frac{z+x}{1-zx}\cdot\frac{x+y}{1-xy}.$$

Example 6. Show that $\left(\dfrac{b}{c}+\dfrac{c}{b}\right)^2+\left(\dfrac{c}{a}+\dfrac{a}{c}\right)^2+\left(\dfrac{a}{b}+\dfrac{b}{a}\right)^2$

$=4+\left(\dfrac{b}{c}+\dfrac{c}{b}\right)\left(\dfrac{c}{a}+\dfrac{a}{c}\right)\left(\dfrac{a}{b}+\dfrac{b}{a}\right)$. [C U Entr Paper, 1867]

We have

$$\left(\frac{c}{a}+\frac{a}{c}\right)^2+\left(\frac{a}{b}+\frac{b}{a}\right)^2=\left\{\frac{c^2}{a^2}+2+\frac{a^2}{c^2}\right\}+\left\{\frac{a^2}{b^2}+2+\frac{b^2}{a^2}\right\}$$

$$=4+a^2\left(\frac{1}{b^2}+\frac{1}{c^2}\right)+\frac{1}{a^2}\left(b^2+c^2\right)$$

$$=4+\frac{a^2}{bc}\left(\frac{bc}{b^2}+\frac{bc}{c^2}\right)+\frac{bc}{a^2}\left(\frac{b^2}{bc}+\frac{c^2}{bc}\right)$$

$$=4+\frac{a^2}{bc}\left(\frac{c}{b}+\frac{b}{c}\right)+\frac{bc}{a^2}\left(\frac{b}{c}+\frac{c}{b}\right)$$

$$=4+\left(\frac{b}{c}+\frac{c}{b}\right)\left(\frac{a^2}{bc}+\frac{bc}{a^2}\right);$$

the given expression

$$=4+\left(\frac{b}{c}+\frac{c}{b}\right)\left\{\left(\frac{b}{c}+\frac{c}{b}\right)+\left(\frac{a^2}{bc}+\frac{bc}{a^2}\right)\right\}$$

$$=4+\left(\frac{b}{c}+\frac{c}{b}\right)\left\{\left(\frac{b}{c}+\frac{bc}{a^2}\right)+\left(\frac{c}{b}+\frac{a^2}{bc}\right)\right\}$$

$$=4+\left(\frac{b}{c}+\frac{c}{b}\right)\left\{\frac{b}{a}\left(\frac{a}{c}+\frac{c}{a}\right)+\frac{a}{b}\left(\frac{c}{a}+\frac{a}{c}\right)\right\}$$

$$=4+\left(\frac{b}{c}+\frac{c}{b}\right)\left(\frac{c}{a}+\frac{a}{c}\right)\left(\frac{a}{b}+\frac{b}{a}\right).$$

Example 7. If $2s=a+b+c$, show that

$$\frac{1}{s-a}+\frac{1}{s-b}+\frac{1}{s-c}-\frac{1}{s}=\frac{abc}{s(s-a)(s-b)(s-c)}.$$

We have $$\frac{1}{s-a}+\frac{1}{s-b}=\frac{2s-a-b}{(s-a)(s-b)}=\frac{c}{(s-a)(s-b)},$$

and $$\frac{1}{s-c}-\frac{1}{s}=\frac{s-(s-c)}{(s-c)}=\frac{c}{s(s-c)}.$$

Hence, the given expression

$$=\frac{c}{(s-a)(s-b)}+\frac{c}{s(s-c)}$$

$$=c\,\frac{s(s-c)+(s-a)(s-b)}{s(s-a)(s-b)(s-c)}$$

$$=c\,\frac{2s^2-s(a+b+c)+ab}{s(s-a)(s-b)(s-c)}$$

$$=\frac{abc}{s(s-a)(s-b)(s-c)}. \quad [\; 2s^2-s(a+b+c)=2s^2-2s^2=0\,]$$

Example 8. Show that

$$\frac{a+b}{ab}\left(a^2+b^2-c^2\right)+\frac{b+c}{bc}\left(b^2+c^2-a^2\right)+\frac{c+a}{ca}\left(c^2+a^2-b^2\right)=2(a+b+c).$$

Putting $2s^2$ for $a^2+b^2+c^2$, we have

$$a^2+b^2-c^2=(a^2+b^2+c^2)-2c^2=2(s^2-c^2),$$
$$b^2+c^2-a^2=(a^2+b^2+c^2)-2a^2=2(s^2-a^2),$$
$$c^2+a^2-b^2=(a^2+b^2+c^2)-2b^2=2(s^2-b^2)$$

Hence, the given expression

$$=2\left(\frac{1}{b}+\frac{1}{a}\right)\left(s^2-c^2\right)+2\left(\frac{1}{c}+\frac{1}{b}\right)\left(s^2-a^2\right)$$
$$+2\left(\frac{1}{a}+\frac{1}{c}\right)\left(s^2-b^2\right)$$

$$=2\left\{\frac{1}{a}\left(2s^2-b^2-c^2\right)+\frac{1}{b}\left(2s^2-c^2-a^2\right)+\frac{1}{c}\left(2s^2-a^2-b^2\right)\right\}$$
$$=2\left\{\frac{1}{a}\cdot a^2+\frac{1}{b}\cdot b^2+\frac{1}{c}\cdot c^2\right\}$$
$$=2(a+b+c)$$

Example 9. Show that

$$\frac{a}{a^2-1}+\frac{a^2}{a^4-1}+\frac{a^4}{a^8-1}=\frac{1}{2}\left(\frac{a+1}{a-1}-\frac{a^8+1}{a^8-1}\right);$$

$$\frac{a}{a^2-1}=\frac{1}{2}\cdot\frac{2a}{a^2-1}=\frac{1}{2}\cdot\frac{(a+1)^2-(a^2+1)}{a^2-1}$$
$$=\frac{1}{2}\cdot\left(\frac{a+1}{a-1}-\frac{a^2+1}{a^2-1}\right);$$
$$\frac{a^2}{a^4-1}=\frac{1}{2}\cdot\frac{2a^2}{a^4-1}=\frac{1}{2}\cdot\frac{(a^2+1)^2-(a^4+1)}{a^4-1}$$
$$=\frac{1}{2}\cdot\left(\frac{a^2+1}{a^2-1}-\frac{a^4+1}{a^4-1}\right);$$
$$\frac{a^4}{a^8-1}=\frac{1}{2}\cdot\frac{2a^4}{a^8-1}=\frac{1}{2}\cdot\frac{(a^4+1)^2-(a^8+1)}{a^8-1}$$
$$=\frac{1}{2}\cdot\left(\frac{a^4+1}{a^4-1}-\frac{a^8+1}{a^8-1}\right).$$

Hence the given expression

$$=\frac{1}{2}\cdot\left\{\left(\frac{a+1}{a-1}-\frac{a^2+1}{a^2-1}\right)+\left(\frac{a^2+1}{a^2-1}-\frac{a^4+1}{a^4-1}\right)+\left(\frac{a^4+1}{a^4-1}-\frac{a^8+1}{a^8-1}\right)\right\}$$
$$=\frac{1}{2}\cdot\left\{\frac{a+1}{a-1}-\frac{a^8+1}{a^8-1}\right\}.$$

Example 10. Show that

$$bc\frac{a+d}{(a-b)(a-c)}+ac\frac{b+d}{(b-a)(b-c)}+ab\frac{c+d}{(c-a)(c-b)}=d$$

Since $\quad b-a=-(a-b),$

and $\quad (c-a)(c-b)=[-(a-c)]\times[-(b-c)]=(a-c)(b-c),$

$\therefore$ the given expression

$$=bc\frac{a+d}{(a-b)(a-c)}+ac\frac{-(b+d)}{(a-b)(b-c)}+ab\frac{c+d}{(a-c)(b-c)}$$
$$=\frac{bc(a+d)(b-c)-ac(b+d)(a-c)+ab(c+d)(a-b)}{(a-b)(a-c)(b-c)}.$$

Now, the numerator $= abc\{(b-c)-(a-c)+(a-b)\}$
$+d\{bc(b-c)-ac(a-c)+ab(a-b)\}$
$=d\{bc(b-c)-ac(a-c)+ab(a-b)\}$
$=d\{a^2(b-c)+b^2(c-a)+c^2(a-b)\}$
$=d(a-b)(a-c)(b-c)$

Hence, the given expression $=d$

Example 11. Simplify

$$\frac{a^2}{(a-b)(a-c)(x+a)}+\frac{b^2}{(b-a)(b-c)(x+b)}+\frac{c^2}{(c-a)(c-b)(x+c)}.$$

The given expression

$$=\frac{a^2}{(a-b)(a-c)(x+a)}+\frac{-b^2}{(a-b)(b-c)(x+b)}+\frac{c^2}{(a-c)(b-c)(x+c)}$$

$$=\frac{a^2(b-c)(x+b)(x+c)-b^2(a-c)(x+c)(x+a)+c^2(a-b)(x+a)(x+b)}{(a-b)(a-c)(b-c)(x+a)(x+b)(x+c)}$$

Now, the numerator

$$=a^2(b-c)\{x^2+x(b+c)+bc\}+b^2(c-a)\{x^2+x(c+a)+ca\}$$
$$+c^2(a-b)\{x^2+x(a+b)+ab\}$$
$$=x^2\{a^2(b-c)+b^2(c-a)+c^2(a-b)\}$$
$$+x\{a^2(b^2-c^2)+b^2(c^2-a^2)+c^2(a^2-b^2)\}$$
$$+abc\{a(b-c)+b(c-a)+c(a-b)\}$$
$$=x^2\{a^2(b-c)+b^2(c-a)+c^2(a-b)\}$$
$$=x^2(a-b)(a-c)(b-c)$$

Hence, the given expression $=\dfrac{x^2}{(x+a)(x+b)(x+c)}.$

Example 12. Simplify

$$\frac{a^3}{(a-b)(a-c)}+\frac{b^3}{(b-c)(b-a)}+\frac{c^3}{(c-a)(c-b)}.$$

[C. U Entr Paper, 1887.]

The given expression

$$=\frac{a^3}{(a-b)(a-c)}+\frac{-b^3}{(b-c)(a-b)}+\frac{c^3}{(a-c)(b-c)}$$

$$=\frac{a^3(b-c)-b^3(a-c)+c^3(a-b)}{(a-b)(a-c)(b-c)}.$$

Now, the numerator $=a^3(b-c)+b^3(c-a)+c^3(a-b)$
$=(a-b)(a-c)(b-c)(a+b+c)$

Hence, the given expression $=a+b+c$

† Alternative Method :

Since $\frac{1}{(a-b)(a-c)}=\frac{1}{(a-b)(b-c)}-\frac{1}{(a-c)(b-c)}$.

$\therefore$ the given expression

$$=\left\{\frac{a^3}{(a-b)(b-c)}-\frac{a^3}{(a-c)(b-c)}\right\}+\frac{-b^3}{(a-b)(b-c)}+\frac{c^3}{(a-c)(b-c)}$$

$$=\frac{a^3-b^3}{(a-b)(b-c)}-\frac{a^3-c^3}{(a-c)(b-c)}$$

$$=\frac{a^2+ab+b^2}{b-c}-\frac{a^2+ac+c^2}{b-c}$$

$$=\frac{a(b-c)+(b^2-c^2)}{b-c}=a+b+c$$

Example 13. If $\frac{1}{a^2}+\frac{1}{b^2}+\frac{1}{c^2}-\frac{1}{bc}-\frac{1}{ca}-\frac{1}{ab}=0$,

prove that $a=b=c$

$$\frac{1}{a^2}+\frac{1}{b^2}+\frac{1}{c^2}-\frac{1}{bc}-\frac{1}{ca}-\frac{1}{ab}=0,$$

or, $\frac{1}{2}\left\{\left(\frac{1}{b}-\frac{1}{c}\right)^2+\left(\frac{1}{c}-\frac{1}{a}\right)^2+\left(\frac{1}{a}-\frac{1}{b}\right)^2\right\}=0$

[Formula XXIV, Art, 133]

Now, as *none* of the terms of the left-hand expression is negative, this equation cannot hold unless *each* of those terms is zero

Hence, $\frac{1}{b}-\frac{1}{c}=0$, $b=c$,

$\frac{1}{c}-\frac{1}{a}=0$; $c=a$,

and $\frac{1}{a}-\frac{1}{b}=0$, $a=b$

Thus, $a=b=c$

EXERCISE 91.

Prove that

1. $\frac{a}{ax+x^2}+\frac{b}{bx+x^2}+\frac{c}{cx+x^2}=\frac{3}{x}-\frac{1}{a+x}-\frac{1}{b+x}-\frac{1}{c+x}$.

[B U 1920]

†This method is due to my friend and pupil Babu Bimala Charan Shome, Head Assistant, Forest Surveys, Dehra Dun

2. $\dfrac{1+x^2}{(x+y)(x+z)}+\dfrac{1+y^2}{(y+z)(y+x)}+\dfrac{1+z^2}{(z+x)(z+y)}=3$

if $yz+zx+xy=1$

3. $(a+b+c)\left(\dfrac{1}{a}+\dfrac{1}{b}+\dfrac{1}{c}\right)=1+(b+c)(c+a)(a+b)$,

if $abc=1$

4. $\dfrac{1}{a^2-bc}+\dfrac{1}{b^2-ca}+\dfrac{1}{c^2-ab}=0$, if $bc+ca+ab=0$

5. $\dfrac{x+yz}{(y+x)(z+x)}+\dfrac{y+zx}{(y+z)(y+x)}+\dfrac{z+xy}{(z+x)(z+y)}=3$,

if $x+y+z=1$.

6. $\dfrac{x}{1-x^2}+\dfrac{y}{1-y^2}+\dfrac{z}{1-z^2}=\dfrac{4xyz}{(1-x^2)(1-y^2)(1-z^2)}$,

if $x+y+z=xyz$

7. $\left(\dfrac{y-z}{x}+\dfrac{z-x}{y}+\dfrac{x-y}{z}\right)\left(\dfrac{x}{y-z}+\dfrac{y}{z-x}+\dfrac{z}{x-y}\right)=9$,

if $x+y+z=0$.

8. $\dfrac{1}{a^3}+\dfrac{1}{b^3}+\dfrac{1}{c^3}=\dfrac{1}{a^3+b^3+c^3}=\dfrac{1}{(a+b+c)^3}$,

if $\dfrac{1}{a}+\dfrac{1}{b}+\dfrac{1}{c}=\dfrac{1}{a+b+c}$.

9. $\dfrac{(b-c)^2}{(c-a)(a-b)}+\dfrac{(c-a)^2}{(a-b)(b-c)}+\dfrac{(a-b)^2}{(b-c)(c-a)}=3$

10. $\dfrac{(b^2-c^2)^3+(c^2-a^2)^3+(a^2-b^2)^3}{a^3(b-c)^3+b^3(c-a)^3+c^3(a-b)^3}=\dfrac{(b+c)(c+a)(a+b)}{abc}$.

11. $\dfrac{x^6}{x^2+y^2}=x^4-x^2y^2+y^4-\dfrac{y^6}{x^2+y^2}$.

12. $\dfrac{x^6}{x^2-y^2}=x^4+x^2y^2+y^4+\dfrac{y^6}{x^2-y^2}$.

13. $\dfrac{x^2yz+xy^2z+xyz^2}{x^2y^2z^2}=\dfrac{1}{yz}+\dfrac{1}{zx}+\dfrac{1}{xy}$.

14. $\dfrac{xy^2z^2+yz^2x^2+zx^2y^2}{x^2y^2z^2}=\dfrac{1}{x}+\dfrac{1}{y}+\dfrac{1}{z}$.

15. $\dfrac{3a-6}{(a-1)(a-2)(a-3)}$

$=\dfrac{1}{(a-2)(a-3)}+\dfrac{1}{(a-3)(a-1)}+\dfrac{1}{(a-1)(a-2)}$.

16. $$\frac{3x^2-14}{(x+1)(x+2)(x+3)}$$
$$=\frac{x-1}{(x+2)(x+3)}+\frac{x-2}{(x+3)(x+1)}+\frac{x-3}{(x+1)(x+2)}.$$

17. $$\frac{1-x}{1+x}=1-2x+2x^2-2x^3+\frac{2x^4}{1+x}.$$

18. $$\frac{a}{x^2-a^2}=\frac{a}{x^2}+\frac{a^3}{x^4}+\frac{a^5}{x^6}+\frac{a^7}{x^6(x^2-a^2)}.$$

19. $$\frac{a^3}{x^3+a^3}=\frac{a^3}{x^3}-\frac{a^6}{x^6}+\frac{a^9}{x^9}-\frac{a^{12}}{x^9(x^3+a^3)}$$
$$=1-\frac{x^3}{a^3}+\frac{x^6}{a^6}-\frac{x^9}{a^9}+\frac{x^{12}}{a^9(x^3+a^3)}.$$

20. $$\frac{x^4-1}{x+a}=x^3-ax^2+a^2x-a^3+\frac{a^4-1}{x+a}.$$

21. Find the value of
$$\frac{x+2a}{2b-x}+\frac{x-2a}{2b+x}+\frac{4ab}{x^2-4b^2}, \text{ when } x=\frac{ab}{a+b}.$$

22. Show that $\dfrac{x+a}{x-a}+\dfrac{x+b}{x-b}+\dfrac{x+c}{x-c}-3$
$$=\frac{6abc}{(x-a)(x-b)(x-c)}, \text{ if } x=\frac{2(ab+bc+ca)}{a+b+c}.$$

23. If $x=\dfrac{ab+bc+ca}{a+b+c}$, show that
$$\frac{a+2x}{a-2x}+\frac{b+2x}{b-2x}+\frac{c+2x}{c-2x}+3=\frac{6abc}{(a-2x)(b-2x)(c-2x)}.$$

24. Find the value of
$$\frac{x^2-(b+c)x}{(x-b)(x-c)}+\frac{x^2-(c+a)x}{(x-c)(x-a)}+\frac{x^2-(a+b)x}{(x-a)(x-b)},$$
$$\text{when } x=\frac{3abc}{ab+bc+ca}.$$

25. Find the value of
$$\frac{x^2-y^2+x}{y^2-x^2+y}, \text{ when } x=\frac{a-b}{a+b} \text{ and } y=\frac{a+b}{a-b}.$$
[C U Entr Paper, 1883]

[The given expression $=\dfrac{x(x+1)-y^2}{y(y+1)-x^2}=$ &c]

26. Find the value of $\dfrac{x^4+3abx^2-10a^2b^2}{x^4+7abx^2+10a^2b^2}\times\dfrac{a^2+2ab+b^2}{a^2-2ab+b^2}$,

when $x^2=a^2+b$

27. Find the value of

$$\frac{x^2y^2+3(2x^2-y^2)ab-18a^2b^2}{y^4+9aby^2+18a^2b^2}\times\frac{a^3-b^3}{a^3+b^3},$$

when $x=a+b$ and $y=a-b$

28. Find the value of

$$\frac{x^4+abx^2-2a^2b^2}{x^2y^2+(x^2+2y^2)ab+2a^2b^2}-\frac{a^2+ab+b^2}{a^2-ab+b^2},$$

when $x=a+b$ and $y=a-b$.

29. Simplify $\dfrac{x^9}{x^3+1}+\dfrac{x^6}{x^3-1}+\dfrac{1}{x^3+1}-\dfrac{1}{x^3-1}$.

30. Simplify $\dfrac{x^2-(a-b)^2}{(x+b)^2-a^2}+\dfrac{a^2-(x-b)^2}{(x+a)^2-b^2}+\dfrac{b^2-(x-a)^2}{(a+b)^2-x^2}$.

31. Simplify $\dfrac{(a+2b)^2-b^2}{(a+b)^2-4b^2}+\dfrac{(a-b)^2-4b^2}{(a-2b)^2-b^2}+\dfrac{(2a+3b)^2-b^2}{(2a+b)^2-9b^2}$.

32. Simplify $\dfrac{x^4-(x-1)^2}{(x^2+1)^2-x^2}+\dfrac{x^2-(x^2-1)^2}{x^2(x+1)^2-1}+\dfrac{x^2(x-1)^2-1}{x^4-(x+1)^2}$.

33. If $2s=a+b+c$, show that

$$1-\frac{a^2+b^2-c^2}{2ab}=\frac{2(s-a)(s-b)}{ab}.$$

34. Simplify $\dfrac{b-c}{a^2-(b-c)^2}+\dfrac{c-a}{b^2-(c-a)^2}+\dfrac{a-b}{c^2-(a-b)^2}$.

35. Simplify

$$\frac{a+b}{2ab}(a+b-c)+\frac{b+c}{2bc}(b+c-a)+\frac{c+a}{2ca}(c+a-b)$$

36. Simplify

$$\frac{x+y}{2xy}(x^2+y^2-z^2)+\frac{y+z}{2yz}(y^2+z^2-x^2)+\frac{z+x}{2zx}(z^2+x^2-y^2)$$

37. Simplify

$$\frac{a+b}{2ab}(a^3+b^3-c^3)+\frac{b+c}{2bc}(b^3+c^3-a^3)+\frac{c+a}{2ca}(c^3+a^3-b^3)$$

38. If $x=\dfrac{b^2+c^2-a^2}{2bc}$, $y=\dfrac{a^2+c^2-b^2}{2ca}$ and $z=\dfrac{a^2+b^2-c^2}{2ab}$,
find in its simplest form, the value of $(b+c)x+(c+a)y+(a+b)z$.

39. If $p=\dfrac{a-b}{x-c}$, $q=\dfrac{b-c}{x-a}$, $r=\dfrac{c-a}{x-b}$, find the value of $p+q+r+pqr$.

40. Show that

$$\left(\frac{1}{b-c}+\frac{1}{c-a}+\frac{1}{a-b}\right)^2=\frac{1}{(b-c)^2}+\frac{1}{(c-a)^2}+\frac{1}{(a-b)^2}.$$

41. Show that

$$\frac{1}{1+x}+\frac{2x}{1+x^2}+\frac{4x^3}{1+x^4}+\frac{8x^7}{1+x^8}=\frac{1}{1-x}-\frac{16x^{15}}{1-x^{16}}.$$

Simplify

42. $\dfrac{1}{(a-b)(a-c)}+\dfrac{1}{(b-a)(b-c)}+\dfrac{1}{(c-a)(c-b)}.$

43. $\dfrac{a^2}{(a-b)(a-c)}+\dfrac{b^2}{(b-a)(b-c)}+\dfrac{c^2}{(c-a)(c-b)}.$ [A U 1925]

44. $\dfrac{x^2+yz}{(x-y)(x-z)}+\dfrac{y^2+zx}{(y-z)(y-x)}+\dfrac{z^2+xy}{(z-x)(z-y)}.$

45. $\dfrac{2a^2-bc}{(a-b)(a-c)}+\dfrac{2b^2-ca}{(b-c)(b-a)}+\dfrac{2c^2-ab}{(c-a)(c-b)}.$

46. $\dfrac{x^2-yz}{(x-y)(x-z)}+\dfrac{y^2+zx}{(y+z)(y-x)}+\dfrac{z^2+xy}{(z-x)(z+y)}.$ [C U 1865]

47. $\dfrac{1}{x(x-y)(x-z)}+\dfrac{1}{y(y-x)(y-z)}+\dfrac{1}{z(z-x)(z-y)}.$

[C U Entr Paper, 1872]

48. $\dfrac{1}{(a-b)(a-c)(x-a)}+\dfrac{1}{(b-a)(b-c)(x-b)}+\dfrac{1}{(c-a)(c-b)(x-c)}$

49. $\dfrac{a}{(a-b)(a-c)(x-a)}+\dfrac{b}{(b-a)(b-c)(x-b)}+\dfrac{c}{(c-a)(c-b)(x-c)}.$

50. $\dfrac{a^2}{(a-b)(a-c)(x-a)}+\dfrac{b^2}{(b-a)(b-c)(x-b)}+\dfrac{c^2}{(c-a)(c-b)(x-c)}$

51. $\dfrac{a^2+ha+k}{(a-b)(a-c)(x-a)}+\dfrac{b^2+hb+k}{(b-a)(b-c)(x-b)}+\dfrac{c^2+hc+k}{(c-a)(c-b)(x-c)}.$

52. Show that

$$\frac{a^2\left(\frac{1}{b}-\frac{1}{c}\right)+b^2\left(\frac{1}{c}-\frac{1}{a}\right)+c^2\left(\frac{1}{a}-\frac{1}{b}\right)}{a\left(\frac{1}{b}-\frac{1}{c}\right)+b\left(\frac{1}{c}-\frac{1}{a}\right)+c\left(\frac{1}{a}-\frac{1}{b}\right)}=a+b+c$$

53. Show that

$$\frac{a^3(b^2-c^2)+b^3(c^2-a^2)+c^3(a^2-b^2)}{a^2(b-c)+b^2(c-a)+c^2(a-b)}=ab+bc+ca$$

54. Show that

$$\frac{a(a+b)(a+c)}{(a-b)(a-c)}+\frac{b(b+a)(b+c)}{(b-a)(b-c)}+\frac{c(c+a)(c+b)}{(c-a)(c-b)}=a+b+c$$

55. Prove that $\dfrac{bc}{a(a^2-b^2)(a^2-c^2)}+\dfrac{ac}{b(b^2-a^2)(b^2-c^2)}$

$$+\frac{ab}{c(c^2-b^2)(c^2-a^2)}=\frac{1}{abc}.$$

56. Simplify $\dfrac{bc(x-a)^2}{(a-b)(a-c)}+\dfrac{ca(x-b)^2}{(b-c)(b-a)}+\dfrac{ab(x-c)^2}{(c-a)(c-b)}.$

Miscellaneous Exercises. V

I

1. Express the following as the difference of two squares

(i) $(x+7)(x+9)(x+11)(x+13)$,

(ii) $(x+1)(x+2)(x+3)(x+4)-15$

2. Factorise $7(z+x)^3-(x-y)^3-(y+z)^3$

3. Simplify $(a-b)^2(a+b-2c)^2+(b-c)^2(b+c-2a)^2$
$+(c-a)^2(c+a-2b)^2$, when $a+b+c=0$.

4. If $x+y+z=4xyz$, show that

$$\frac{x}{1-4x^2}+\frac{y}{1-4y^2}+\frac{z}{1-4z^2}=\frac{16xyz}{(1-4x^2)(1-4y^2)(1-4z^2)}.$$

5. If $2s=a+b+c$, show that

$$1-\left(\frac{b^2+c^2-a^2}{2bc}\right)^2=\frac{4s(s-a)(s-b)(s-c)}{b^2c^2}.$$

6. Show that $\dfrac{(b+c)(b^2+c^2-a^2)}{2bc}+\dfrac{(c+a)(c^2+a^2-b^2)}{2ca}$

$$+\frac{(a+b)(a^2+b^2-c^2)}{2ab}=a+b+c.$$

7. Find the value of $\dfrac{qr}{(a-q)(a-r)}+\dfrac{rp}{(a-r)(a-p)}$

$$+\frac{pq}{(a-p)(a-q)}, \text{ when } \frac{1}{a}=\frac{1}{3}\left(\frac{1}{p}+\frac{1}{q}+\frac{1}{r}\right).$$

8. Show that $(x^2-y^2)^3+(y^2-z^2)^3+(z^2-x^2)^3$ is divisible by each of the expressions x^2-y^2, y^2-z^2 and z^2-x^2

II

1. If $x+y+z=15$, $xy+yz+zx=75$, find the value of $x^3+y^3+z^3-3xyz$

2. Show that $(a+b-2c)^3+(b+c-2a)^3+(c+a-2b)^3$
$$=3(a+b-2c)(b+c-2a)(c+a-2b).$$

3. Show that $(b-c)(b+c-2a)^2+(c-a)(c+a-2b)^2$
$$+(a-b)(a+b-2c)^2=9(a-b)(b-c)(a-c)$$

4. Simplify $\dfrac{1}{bc(b-a)(c-a)}+\dfrac{1}{ca(c-b)(a-b)}+\dfrac{1}{ab(a-c)(b-c)}.$

5. Find the value of

$$\frac{y}{x}+\frac{y-1}{x+1}, \text{ when } x=\frac{b}{a-b} \text{ and } y=\frac{a}{a+b}.$$

6. Find the H C F of $ab+2a^2-3b^2-4bc-ac-c^2$ and $9ac+2a^2-5ab+4c^2+8bc-12b^2$

7. Find the L C M of

$$6x^3-11x^2+5x-3 \text{ and } 9x^3-9x^2+5x-2$$

8. Resolve the following into factors

$$(a-b)(b+c)(c+a)+(b-c)(c+a)(a+b)+(c-a)(a+b)(b+c)$$

III.

1. Expand $\left(x+\dfrac{2}{x}\right)^5$ in a series of descending powers of x

2. Show that $(a+b+c)^3-a^3-b^3-c^3=3(a+b)(b+c)(c+a)$

Hence prove that

$$(x+y+z)^3-(y+z-x)^3-(z+x-y)^3-(x+y-z)^3=24xyz.$$

3. Find the value of $a^3-b^3+c^3+3abc$ when $a=$ 4278, $b=$1 2345 and $c=$ 8067

4. Show that $(x-a)^2(b-c)+(x-b)^2(c-a)+(x-c)^2(a-b)$
$= (a-b)(a-c)(b-c)$

5. Find the H C F of
$6x^3-25x^2+23x-6$, $2x^2-7x+3$ and $6x^2-7x+2$

6. Find the H C F of $x^5+11x-12$ and x^5+11x^3+54

7. Simplify $\dfrac{a^3(b+c)}{(c-a)(b-a)}+\dfrac{b^3(c+a)}{(a-b)(c-b)}+\dfrac{c^3(a+b)}{(a-c)(b-c)}$.

8. Show that $a^3(b^2-c^2)+b^3(c^2-a^2)+c^3(a^2-b^2)$ is exactly divisible by each of $b-c$, $c-a$ and $a-b$

IV

1. If $a+b=2$, $ab=7$, find the value of a^5+b^5

2. Resolve $2(a^6+b^6)-ab(a^2+b^2)(2ab-3a^2+3b^2)$ into five factors

3. Find the value of $a^3+b^3+c^3-3abc$, when $a=2658$, $b=2664$ and $c=2678$

4. If $x=b+c-a$, $y=c+a-b$ and $z=a+b-c$, prove that $x^3+y^3+z^3-3xyz=4(a^3+b^3+c^3-3abc)$

5. Find the value of
$$\frac{2x^2+5xy+3y^2}{2x^2+xy-3y^2}, \text{ when } x=\frac{a}{a+b} \text{ and } y=\frac{b}{a-b}.$$

6. Show that $8(a+b+c)^3-(a+b)^3-(b+c)^3-(c+a)^3$
$=3(2a+b+c)(a+2b+c)(a+b+2c)$.

7. Find the L C M of

$x^2-3xy-10y^2$, $x^2+2xy-35y^2$ and $x^2-8xy+15y^2$,

and resolve into simple factors the quotient when the L C M of the above expressions is divided by their H C F

8. Find, without direct substitution the value of $x^5-18x^4+47x^3-31x^2+19x-60$, when $x=15$

V

1. If $x=\dfrac{a-b}{m-c}$, $y=\dfrac{b-c}{m-a}$ and $z=\dfrac{c-a}{m-b}$,

show that $x+y+z+xyz=0$.

2. If $\frac{a}{b}+\frac{c}{d}=\frac{b}{a}+\frac{d}{c}$, prove that $\frac{a^3}{b^3}+\frac{c^3}{d^3}=\frac{b^3}{a^3}+\frac{d^3}{c^3}$.

3. Find the value of $\frac{(x-a)(x-b)}{(x-a-b)^2}$, when $x=\frac{a^2+ab+b^2}{a+b}$.

4. If $x=\frac{2ac}{a+b}$, show that the value of

$\frac{(x-a)^2+(x-c)^2}{a^2+c^2}+\frac{4ac}{(a+c)^2}$ is the same for all values of a and c

5. Resolve the following into factors

(i) $6a^4+43a^3b-56a^2b^2+43ab^3+6b^4$,

(ii) $12x^4-37x^3+45x^2-37x+12$,

(iii) $abx^4+(ac+b^2)x^3+(2ab+bc)x^2+(ac+b^2)x+ab$

6. Show that

$$(x+y)^3-(y+z)^3+(z-x)^3=3(x+y)(y+z)(x-z)$$

7. Find the H C F of

(i) $x^3-(a+p)x^2+(q+ap)x-aq$ and $x^3+ax^2-3a^2x+a^3$.

(ii) $x^3-y^3-z^3-3xyz$ and $x^2-2xy+y^2-2xz+2yz+z^2$

8. Show that, if a rational and integral expression in x vanishes when 'a' is put for x, the expression contains $x-a$ as a factor

VI

1. Show that

$$(a^2-a+1)(b-c)+(b^2-b+1)(c-a)+(c^2-c+1)(a-b)$$
$$=(a^2-a+1)(b^2-c^2)+(b^2-b+1)(c^2-a^2)+(c^2-c+1)(a^2-b^2)$$

2. Show that $\frac{ab}{(x-a)(x-b)}+\frac{bc}{(x-b)(x-c)}+\frac{ca}{(x-c)(x-a)}=0$,

when $\frac{1}{x}=\frac{1}{3}\left(\frac{1}{a}+\frac{1}{b}+\frac{1}{c}\right)$.

3. Prove that

$$a(b-c)^3+b(c-a)^3+c(a-b)^3=0, \text{ when } a+b+c=0$$

4. Express $(x^2+y^2+z^2+2xy)^2-2(x+y)^2z^2$ as the sum of two perfect squares

5. Simplify

$$\left\{\frac{y^2-yz+z^2}{x}+\frac{x^2}{y+z}-\frac{3}{\frac{1}{y}+\frac{1}{z}}\right\}\cdot\frac{\frac{2}{y}+\frac{2}{z}}{\frac{1}{yz}+\frac{1}{zx}+\frac{1}{xy}}+(x+y+z)^2$$

6. Find the H C F of

(i) $x^3+(5m-3)x^2+3m(2m-5)x-18m^2$
and $x^3+(m-3)x^2-m(2m+3)x+6m^2$

(ii) $10x^3-54x^2+87x-45$ and $5x^4-36x^3+87x^2-90x+54$

7. Find the H C F and L C M of
$2x^4+x^3-9x^2+8x-2$ and $2x^4-7x^3+11x^2-8x+2$

8. Show, without actual division, that $x^{55}-y^{55}$ is divisible by $x-y$, and that the remainder when it is divided by $x+y$ is $-2y^{55}$

VII.

1. Divide the continued product of $1+x+y$, $1-x+y$, $1+x-y$ and $x+y-1$ by $1+2xy-x^2-y^2$

2. Simplify $\dfrac{bc(x-a)}{(a-b)(a-c)}+\dfrac{ca(x-b)}{(b-a)(b-c)}+\dfrac{ab(x-c)}{(c-a)(c-b)}$.
[C U 1896]

3. Prove that $2\{(b+c-2a)^4+(c+a-2b)^4+(a+b-2c)^4\}$
$=\{(b+c-2a)^2+(c+a-2b)^2+(a+b-2c)^2\}^2$

4. Reduce the following to their lowest terms

(i) $\dfrac{a^2}{\dfrac{a^2+b^2}{a+b}-b}+\dfrac{b^2}{\dfrac{a^2+b^2}{a+b}-a}$, (ii) $\dfrac{\dfrac{1-x+x^2}{1+x+x^2}+\dfrac{1-x}{1+x}}{\dfrac{1-x+x^2}{1+x+x^2}+\dfrac{1+x}{1-x}}$.

5. Express $41x^2-60xy+104y^2$ in the form of $(px+qy)^2+4(qx-py)^2$, finding the numerical values of p and q.

6. Find the H C F and L C M of
$6x^3-17x^2+11x-2$ and $12x^3-4x^2-3x+1$

7. Show that $m-n$ is a factor of
$(a+b)(m^2+n^2)+am(n-3m)+bn(m-3n)$
For what value of a is x^3+5x+a divisible by $x-3$?

8. Show that the last digit in $3^{2n+1}+2^{2n+1}$ is 5, if n be any positive integer [M M 1868]

VIII

1. Show that
$(a-b)(x-a)(x-b)+(b-c)(x-b)(x-c)+(c-a)(x-c)(x-a)$
$=(a-b)(b-c)(a-c)$.

2. Show that $4(a^2+ab+b^2)^3-(a-b)^2(a+2b)^2(2a+b)^2$
$=27a^2b^2(a+b)^2$ [M M 1888]

3. If $2s=a+b+c$, show that $16s(s-a)(s-b)(s-c)$
$=2a^2b^2+2a^2c^2+2b^2c^2-a^4-b^4-c^4$ [C U 1867]

4. Resolve the following into factors
$$(a^2-b^2)^2+(c^2-d^2)^2-(a+b)^2(c-d)^2-(a-b)^2(c+d)^2$$
[M M 1876]

5. Simplify $\dfrac{(y-z)(y+z)^3+(z-x)(z+x)^3+(x-y)(x+y)^3}{(y+z)(y-z)^3+(z+x)(z-x)^3+(x+y)(x-y)^3}$.
[M M 1892, B M 1888]

6. Simplify $\dfrac{x^2-yz}{(x-y)(x-z)}+\dfrac{y^2+zx}{(y+z)(y-x)}+\dfrac{z^2+xy}{(z-x)(z+y)}$.
[C U 1865]

7. Show that $2^{4n}-1$ is divisible by 15, if n be a positive integer [M M 1875]

8. Find the H C F and L C M of
x^4+2x^2+1, $x^6+x^4-x^2-1$ and x^4-1. [C U 1869]

CHAPTER XXVI

SIMPLE EQUATIONS AND PROBLEMS

I. Simple Equations.

172. We have already explained the process of solving easy simple equations in Chapters V and XVII and shall now consider the subject more fully

173. Solution of equations facilitated by suitable transposition and combination of terms.

The following are typical examples

Example 1. Solve $4(x+1)^2+9(x+2)^2=13(x+3)^2$

Simplifying the sides, we have
$$4(x^2+2x+1)+9(x^2+4x+4)=13(x^2+6x+9),$$
$$\text{or, } 13x^2+44x+40=13x^2+78x+117,$$

or, $13x^2+44x-13x^2-78x=117-40$, [transposing]

i.e, $-34x=77$;

$x=-\frac{77}{34}=-2\frac{9}{34}$

Example 2. Solve $(x-2)^3+(x-6)^3+(x-10)^3$
$=3(x-2)(x-6)(x-10)$

Transposing, we have

$$(x-2)^3+(x-6)^3+(x-10)^3-3(x-2)(x-6)(x-10)=0,$$

or, $\frac{1}{2}\{(x-2)+(x-6)+(x-10)\}[\{(x-6)-(x-10)\}^2$
$+\{(x-10)-(x-2)\}^2+\{(x-2)-(x-6)\}^2]=0$
[factorising the left side by Art 134]

or, $\frac{1}{2}(3x-18)\{(10-6)^2+(-10+2)^2+(-2+6)^2\}=0,$

or, $\frac{1}{2}(3x-18)\,96=0$,

$\therefore\quad 3x-18=0,$

or, $x=6$

174. Fractional Equations.

Example 3. Solve $\dfrac{7x-11}{6}=\dfrac{31x-41}{24}-\dfrac{7x^2-4}{56x-47}.$

By transposition, we have

$$\frac{7x^2-4}{56x-47}=\frac{31x-41}{24}-\frac{7x-11}{6}$$

$$=\frac{(31x-41)-(28x-44)}{24}$$

$$=\frac{3(x+1)}{24}=\frac{x+1}{8}.$$

Multiplying both sides by $8(56x-47)$, we have

$8(7x^2-4)=(x+1)(56x-47),$

or, $56x^2-32=56x^2+9x-47$,

$\therefore\quad -32=9x-47$

Hence, $9x=-32+47=15$,

$\therefore\quad x=\frac{15}{9}=1\frac{2}{3}$

Example 4. Solve $\dfrac{25-\frac{1}{3}x}{x+1}+\dfrac{16x+4\frac{1}{5}}{3x+2}=\dfrac{23}{x+1}+5.$

By transposition, we have

$$\frac{16x+4\frac{1}{5}}{3x+2}-5=\frac{23}{x+1}-\frac{25-\frac{1}{3}x}{x+1};$$

or,
$$\frac{x-5\frac{4}{5}}{3x+2}=\frac{\frac{1}{3}x-2}{x+1}.$$

Hence,
$$(x-5\tfrac{4}{5})(x+1)=(\tfrac{1}{3}x-2)(3x+2),$$

or,
$$x^2-(4\tfrac{4}{5})x-5\tfrac{4}{5}=x^2-(5\tfrac{1}{3})x-4$$

Hence,
$$(5\tfrac{1}{3}-4\tfrac{4}{5})x=5\tfrac{4}{5}-4,$$

or,
$$\tfrac{8}{15}x=1\tfrac{4}{5}=\tfrac{9}{5};$$

$$x=\tfrac{9}{5}\times\tfrac{15}{8}=\tfrac{27}{8}=3\tfrac{3}{8}$$

Example 5. Solve $\dfrac{3}{x-2}+\dfrac{5}{x-6}=\dfrac{8}{x+3}$.

Since,
$$\frac{8}{x+3}=\frac{3}{x+3}+\frac{5}{x+3},$$

we have
$$\frac{3}{x-2}+\frac{5}{x-6}=\frac{3}{x+3}+\frac{5}{x+3}.$$

Hence, by transposition,

$$\frac{3}{x-2}-\frac{3}{x+3}=\frac{5}{x+3}-\frac{5}{x-6},$$

or,
$$\frac{15}{(x-2)(x+3)}=\frac{-45}{(x+3)(x-6)}.$$

Multiplying both sides by $x+3$, and dividing by 15,

we have
$$\frac{1}{x-2}=\frac{-3}{x-6}.$$

Hence,
$$x-6=-3(x-2),$$

$$4x=12, \quad \text{or,} \quad x=3$$

Example 6. Solve $\dfrac{8}{2x-1}+\dfrac{9}{3x-2}=\dfrac{7}{x+1}$.

We have
$$\frac{8}{2x-1}+\frac{9}{3x-1}=\frac{4}{x+1}+\frac{3}{x+1}.$$

Hence, $\left\{\dfrac{8}{2x-1}-\dfrac{4}{x+1}\right\}+\left\{\dfrac{9}{3x-1}-\dfrac{3}{x+1}\right\}=0,$ [By transposition]

or,
$$\frac{12}{(2x-1)(x+1)}+\frac{12}{(3x-1)(x+1)}=0$$

Hence, $$\frac{1}{2x-1}+\frac{1}{3x-1}=0$$

Multiplying both sides by $(2x-1)(3x-1)$,

we have $$(3x-1)+(2x-1)=0$$

Therefore, $5x=2$, or, $x=\frac{2}{5}$

Example 7. Solve $\dfrac{a-c}{2b+x}+\dfrac{b-c}{2a+x}=\dfrac{a+b-2c}{a+b+x}$.

We have $$\frac{a-c}{2b+x}+\frac{b-c}{2a+x}=\frac{(a-c)+(b-c)}{a+b+x}$$
$$=\frac{a-c}{a+b+x}+\frac{b-c}{a+b+x}.$$

Hence, by transposition,
$$(a-c)\left\{\frac{1}{2b+x}-\frac{1}{a+b+x}\right\}=(b-c)\left\{\frac{1}{a+b+x}-\frac{1}{2a+x}\right\}$$

or $$(a-c)\,\frac{a-b}{(2b+x)(a+b+x)}=(b-c)\,\frac{a-b}{(a+b+x)(2a+x)}.$$

Hence $$\frac{a-c}{2b+x}=\frac{b-c}{2a+x};$$
$$(a-c)(2a+x)=(b-c)(2b+x),$$
$$x\{(a-c)-(b-c)\}=2b(b-c)-2a(a-c),$$
or $$x(a-b)=2(b^2-a^2)-2c(b-a)$$
$$=2(b-a)(b+a-c)$$
$$=2(a-b)(c-a-b),$$
$$x=2(c-a-b)$$

EXERCISE 92.

Solve the following equations.

1. $3(x+1)^2+4(x+3)^2=7(x+2)^2$
2. $(x-a)(x-b)=(x-a-b)^2$.
3. $(x-a)^3+(x-b)^3+(x-c)^3=3(x-a)(x-b)(x-c)$
4. $(x+a)^2+(x+b)^2+(x+c)^2$
$=(x-2a)^2+(x-2b)^2+(x-2c)^2$.
5. $\dfrac{93x-73}{21}=\dfrac{14x-9}{3}-\dfrac{13x-16}{15x-9}$.

6. $\dfrac{95x-159}{35}=\dfrac{19x-29}{7}-\dfrac{17x-47}{23x-59}$.

7. $\dfrac{91x-21}{56}+\dfrac{24x-93}{35x-138}=\dfrac{13x+9}{8}$.

8. $\dfrac{117x-26}{135}+\dfrac{16x-77}{23x-110}=\dfrac{13x+4}{15}+\dfrac{3\frac{4}{5}}{27}$.

9. $\dfrac{6x-7\frac{1}{3}}{13-2x}+2x+\dfrac{1+16x}{24}=4\frac{5}{12}-\dfrac{12\frac{5}{9}-8x}{3}$.

10. $\dfrac{2x+8\frac{1}{2}}{9}-\dfrac{13x-2}{17x-32}+\dfrac{x}{3}=\dfrac{7x}{12}-\dfrac{x+16}{36}$.

11. $\dfrac{41-35x}{105}-\dfrac{7-2x^2}{14(x-1)}=\dfrac{1+3x}{21}-\dfrac{2x-2\frac{1}{5}}{6}$.

12. $\dfrac{1}{x-1}-\dfrac{2}{x+7}=\dfrac{1}{7(x-1)}$. 13. $\dfrac{2}{5(3x+4)}+\dfrac{4}{2x+3}=\dfrac{6}{3x+4}$.

14. $\dfrac{3}{3x-5}-\dfrac{6}{7(4x-7)}=\dfrac{7}{9(3x-5)}+\dfrac{2}{4x-7}$.

15. $\dfrac{11}{12(14x-19)}+\dfrac{7}{9(13x-14)}=\dfrac{3}{14x-19}-\dfrac{2}{13x-14}$.

16. $\dfrac{50}{3x-1}+\dfrac{37-\frac{1}{3}x}{12x-1}=\dfrac{35}{12x-1}+\dfrac{49-\frac{1}{12}x}{3x-1}$.

17. $\dfrac{(1\frac{3}{7})x+19\frac{13}{17}}{2x+5}-\dfrac{\frac{7}{9}x+8}{x+8}=\dfrac{20\frac{13}{17}-(1\frac{4}{7})x}{2x+5}+\dfrac{(1\frac{4}{9})x-9}{2(x+8)}$.

18. $\dfrac{(9\frac{12}{25})x-32}{4x+7}+\dfrac{65x+4\frac{12}{23}}{8x+29}=\dfrac{75x+5\frac{14}{23}}{8x+29}+\dfrac{(4\frac{14}{25})x-29}{4x+7}$.

19. $\dfrac{1}{x-1}+\dfrac{2}{x-2}=\dfrac{3}{x-3}$. 20. $\dfrac{3}{4x+1}+\dfrac{4}{4x+5}=\dfrac{7}{4x+3}$.

21. $\dfrac{15}{3x+11}-\dfrac{8}{3x+17}=\dfrac{7}{3x+5}$.

22. $\dfrac{6}{5x+7}-\dfrac{4}{5x+13}=\dfrac{9}{5x+13}-\dfrac{7}{5x+19}$.

23. $\dfrac{8}{2x+17}-\dfrac{12}{2x+25}=\dfrac{5}{2x+25}-\dfrac{9}{2x+33}$.

24. $\dfrac{5}{3-4x}+\dfrac{9}{4x+13}-\dfrac{4}{4x+5}=0$

25. $\dfrac{6}{5-6x}+\dfrac{13}{6x+19}=\dfrac{7}{6x+7}$. 26. $\dfrac{9}{3-7x}+\dfrac{1}{7x+15}=\dfrac{8}{12-7x}$.

27. $\dfrac{10}{2x-5}+\dfrac{1}{x+5}=\dfrac{18}{3x-5}$. 28. $\dfrac{9}{3x-5}+\dfrac{20}{4x+1}=\dfrac{8}{x+7}$.

29. $\dfrac{12}{3x-8}=\dfrac{20}{4x-13}-\dfrac{1}{x+9}$. 30. $\dfrac{a+b}{x-a}=\dfrac{a}{x-a}+\dfrac{b}{x-b}$.

31. $\dfrac{a^2}{ax-b}+\dfrac{b^2}{bx-a}=\dfrac{a+b}{x+c}$.

32. $\dfrac{m(x+a)}{x+b}+\dfrac{n(x+b)}{x+a}=m+n$

33. $\dfrac{b-c}{x+a}+\dfrac{a-b}{x+b}=\dfrac{a-c}{x+c}$.

34. $\dfrac{2a-3b}{x-a+b}-\dfrac{2b-3a}{x+a-b}=\dfrac{5(a-b)}{x+a+b}$.

35. $\dfrac{1}{x-6a}+\dfrac{2}{x+3a}+\dfrac{3}{x-2a}=\dfrac{6}{x-a}$.

175. Solution of fractional equations facilitated by the division of each numerator by its denominator.

Example 1. Solve $\dfrac{x+1}{x-1}+\dfrac{x+2}{x-2}=\dfrac{22x+30}{11x-18}$.

We have $\dfrac{(x-1)+2}{x-1}+\dfrac{(x-2)+4}{x-2}=\dfrac{2(11x-18)+66}{11x-18}$,

or, $$\left\{1+\frac{2}{x-1}\right\}+\left\{1+\frac{4}{x-2}\right\}=2+\frac{66}{11x-18},$$

or, $$\frac{2}{x-1}+\frac{4}{x-2}=\frac{66}{11x-18}.$$

Hence, by transposition,

$$\frac{2}{x-1}-\frac{22}{11x-18}=\frac{44}{11x-18}-\frac{4}{x-2},$$

or, $$\frac{-14}{(x-1)(11x-18)}=\frac{-16}{(11x-18)(x-2)}.$$

Therefore, $\dfrac{7}{x-1}=\dfrac{8}{x-2}$;

or, $7x-14=8x-8$,

$\therefore$ $x=-6$.

Example 2. Solve $\dfrac{4x^2+7}{2x-1}+\dfrac{6x^2-8x+11}{3x-1}=\dfrac{4x^2+3x+6}{x+1}$.

We have $\dfrac{(4x^2-1)+8}{2x-1}+\dfrac{2x(3x-1)-2(3x-1)+9}{3x-1}$

$$=\frac{4x(x+1)-(x+1)+7}{x+1},$$

or, $\left\{2x+1+\dfrac{8}{2x-1}\right\}+\left\{2x-2+\dfrac{9}{3x-1}\right\}$

$$=4x-1+\frac{7}{x-1}.$$

Hence, $\dfrac{8}{2x-1}+\dfrac{9}{3x-1}=\dfrac{7}{x+1}$.

For the subsequent part of the solution the student is referred to example 6 worked out in Art 174

Example 3. Solve $\dfrac{7x-55}{x-8}+\dfrac{2x-17}{x-9}=\dfrac{6x-71}{x-12}+\dfrac{3x-14}{x-5}$.

We have

$$\frac{7(x-8)+1}{x-8}+\frac{2(x-9)+1}{x-9}=\frac{6(x-12)+1}{x-12}+\frac{3(x-5)+1}{x-5};$$

or, $\left\{7+\dfrac{1}{x-8}\right\}+\left\{2+\dfrac{1}{x-9}\right\}=\left\{6+\dfrac{1}{x-12}\right\}+\left\{3+\dfrac{1}{x-5}\right\}$;

$\therefore$ $\dfrac{1}{x-8}+\dfrac{1}{x-9}=\dfrac{1}{x-12}+\dfrac{1}{x-5}$.

Hence, by transposition,

$$\frac{1}{x-8}-\frac{1}{x-5}=\frac{1}{x-12}-\frac{1}{x-9},$$

or, $\dfrac{3}{(x-8)(x-5)}=\dfrac{3}{(x-12)(x-9)}$;

$\therefore$ $(x-8)(x-5)=(x-12)(x-9)$,

or, $x^2-13x+40=x^2-21x+108$,

$8x=68$, or, $x=8\frac{1}{2}$

EXERCISE 93.

Solve the following equations:

1. $\frac{2x-1}{x-1}+\frac{3x-4}{x-2}=\frac{5x-12}{x-3}$.

2. $\frac{2x+7}{x+2}+\frac{4x+29}{x+6}-\frac{6x-10}{x-3}=3$

3. $\frac{25x-40}{5x-6}-\frac{7x+9}{x+2}+\frac{6x-1}{3x+4}=0$

4. $2+\cfrac{1}{2+\cfrac{3}{2+\cfrac{x}{2}}}=\frac{7}{3}$.

5. $8+\cfrac{2}{3+\cfrac{4}{5+\cfrac{6}{x+2}}}=\frac{214}{25}$

[See Ex 3 worked out in Art. 168]

6. $2+\cfrac{1}{1+\cfrac{1}{1+x}}=\frac{2x+7}{2+x}$.

7. $\frac{15x-7}{5x-4}+\frac{4x+3}{4x-3}=\frac{8x+1}{2x-1}$.

8. $\frac{4x-7}{4x+5}+\frac{15x+11}{5x+7}=\frac{12x+1}{3x+4}$.

9. $\frac{4x^3+4x^2+8x+1}{2x^2+2x+3}=\frac{2x^2+2x+1}{x+1}$.

10. $\frac{12x^3+16x^2+29x-1}{3x^2+4x+8}=\frac{4x^2+20x-1}{x+5}$.

11. $\frac{x^2-x+1}{x-1}+\frac{x^2-2x+1}{x-2}=2x+\frac{2}{x-3}$.

12. $\frac{x^2+3}{x-1}+\frac{x^2-x+1}{x-2}=\frac{2x^2-4x+1}{x-3}$.

13. $\frac{2x^2-3x+7}{2x-1}+\frac{6x^2+2x+21}{3x+1}=\frac{3x^2+8x+7}{x+3}$.

14. $\frac{3+2x}{1+2x}-\frac{5+2x}{7+2x}=1-\frac{4x^2-2}{7+16x+4x^2}$.

15. $\frac{2x-3}{x-2}+\frac{3x-20}{x-7}=\frac{x-3}{x-4}+\frac{4x-19}{x-5}$.

16. $\frac{3x-8}{x-3}+\frac{4x-35}{x-9}=\frac{2x-9}{x-5}+\frac{5x-34}{x-7}$.

17. $\dfrac{3x-13}{x-4}+\dfrac{4x-41}{x-10}=\dfrac{2x-13}{x-6}+\dfrac{5x-41}{x-8}$.

18. $\dfrac{4x+21}{x+5}+\dfrac{5x-69}{x-14}=\dfrac{3x-5}{x-2}+\dfrac{6x-41}{x-7}$.

19. $\dfrac{5-6x}{3x-1}+\dfrac{2x+7}{x+3}=\dfrac{31-12x}{3x-7}+\dfrac{4x+21}{x+5}$.

20. $\dfrac{x^2+3x+3}{x+2}+\dfrac{x^2-15}{x-4}=\dfrac{x^2+7x+11}{x+5}+\dfrac{x^2-4x-20}{x-7}$.

21. $\dfrac{2x+11}{x+5}-\dfrac{9x-9}{3x-4}=\dfrac{4x+13}{x+3}-\dfrac{15x-47}{3x-10}$.

[C U Entr Paper, 1860]

22. $\dfrac{x-2}{x-3}+\dfrac{x-3}{x-4}=\dfrac{x-1}{x-2}+\dfrac{x-4}{x-5}$. [C U Entr Paper, 1887]

176. Miscellaneous Examples.

Example 1. Solve $\dfrac{3abc}{a+b}+\dfrac{a^2b^2}{(a+b)^3}+\dfrac{(2a+b)b^2x}{a(a+b)^2}=3cx+\dfrac{bx}{a}$.

By transposition, we have

$$\frac{ab}{a+b}\left\{3c+\frac{ab}{(a+b)^2}\right\}=x\left\{3c+\frac{b}{a}-\frac{(2a+b)b^2}{a(a+b)^2}\right\}$$

$$=x\left\{3c+\frac{b}{a}\left[1-\frac{(2a+b)b}{(a+b)^2}\right]\right\}$$

$$=x\left\{3c+\frac{b}{a}\,\frac{a^2}{(a+b)^2}\right\}$$

$$=x\left\{3c+\frac{ab}{(a+b)^2}\right\}.$$

Therefore, $\qquad x=\dfrac{ab}{a+b}$.

Example 2. Solve $\dfrac{ax^2+bx+c}{px^2+qx+r}=\dfrac{ax+b}{px+q}$

We have $\qquad \dfrac{x(ax+b)+c}{x(px+q)+r}=\dfrac{ax+b}{px+q}$.

Hence, putting m for $ax+b$ and n for $px+q$,

we have $\qquad \dfrac{mx+c}{nx+r}=\dfrac{m}{n}$;

$$mnx+cn=mnx+rm,$$

$$cn=rm,$$

$$\text{or,}\qquad c(px+q)=r(ax+b),$$
$$x(cp-ar)=br-cq,$$
$$\therefore\qquad x=\frac{br-cq}{cp-ar}.$$

Example 3. Solve $(x-2a)^3+(x-2b)^3=2(x-a-b)^3$

By transposition, we have

$(x-2a)^3-(x-a-b)^3=(x-a-b)^3-(x-2b)^3.$

Putting X for $x-2a$, Y for $x-2b$ and Z for $x-a-b$, we have

$$X^3-Z^3=Z^3-Y^3,$$
$$\text{or,}\quad (X-Z)(X^2+XZ+Z^2)=(Z-Y)(Z^2+ZY+Y^2)$$

But $X-Z=Z-Y$, because each of them $=b-a$,

$$X^2+XZ+Z^2=Z^2+ZY+Y^2$$

Hence, by transposition,

$$X^2-Y^2=Z(Y-X)$$

Removing the common factor $X-Y$, which $=2b-2a$, we have $\quad X+Y=-Z,$

i e, $\quad (x-2a)+(x-2b)=-(x-a-b).$

Hence, $\qquad 3x=3(a+b)$ and $\therefore\ x=a+b$

Example 4. Solve $\dfrac{x+a}{x+b}=\left(\dfrac{2x+a+c}{2x+b+c}\right)^2.$

Since $\qquad \dfrac{x+a}{x+b}=\dfrac{(x+b)+(a-b)}{x+b}=1+\dfrac{a-b}{x+b},$

and $\qquad \dfrac{2x+a+c}{2x+b+c}=\dfrac{(2x+b+c)+(a-b)}{2x+b+c}=1+\dfrac{a-b}{2x+b+c},$

we have $\qquad 1+\dfrac{a-b}{x+b}=\left\{1+\dfrac{a-b}{2x+b+c}\right\}^2$

$$=1+\frac{2(a-b)}{2x+b+c}+\frac{(a-b)^2}{(2x+b+c)^2}.$$

Hence, transposing and dividing by $a-b$, we have

$$\frac{1}{x+b}-\frac{2}{2x+b+c}=\frac{a-b}{(2x+b+c)^2},$$

$$\text{or,}\quad \frac{c-b}{(x+b)(2x+b+c)}=\frac{a-b}{(2x+b+c)^2};$$

$$\therefore \quad \frac{c-b}{x+b}=\frac{a-b}{2x+b+c},$$

$$2x(c-b)+(c^2-b^2)=x(a-b)+b(a-b).$$

$$\therefore \quad x(a+b-2c)=c^2-ab,$$

$$\therefore \quad x=\frac{c^2-ab}{a+b-2c}.$$

Example 5. Solve

$$\frac{4x}{3}-\frac{125x^2-5}{(5x-1)(x+5)}=5x-\frac{5}{3}\cdot\frac{3x^2-1}{x+5}-\frac{95-4x}{3}.$$

Since $$\frac{125x^2-5}{(5x-1)(x+5)}=\frac{5(25x^2-1)}{(5x-1)(x+5)}=\frac{5(5x+1)}{x+5},$$

and $$\frac{5}{3}\cdot\frac{3x^2-1}{x+5}=\frac{\frac{5}{3}(3x^2-1)}{x+5}=\frac{5x^2-\frac{5}{3}}{x+5},$$

we have $$\frac{4x}{3}-\frac{5(5x+1)}{x+5}=5x-\frac{5x^2-\frac{5}{3}}{x+5}-\frac{95}{3}+\frac{4x}{3}.$$

Hence, transposing and dividing by 5, we have

$$\frac{x^2-\frac{1}{3}-(5x+1)}{x+5}=x-6\tfrac{1}{3}.$$

Hence, $$x^2-5x-1\tfrac{1}{3}=x^2-(1\tfrac{1}{3})x-31\tfrac{2}{3},$$

$$\therefore \quad (3\tfrac{2}{3})x=30\tfrac{1}{3},$$

$$\therefore \quad x=\tfrac{91}{11}=8\tfrac{3}{11}.$$

EXERCISE 94.

Solve the following equations.

1. $\dfrac{2x}{x-4}+\dfrac{7x-3}{x+1}=9.$ **2.** $\dfrac{x+4a+b}{x+a+b}+\dfrac{4x+a+2b}{x+a-b}=5.$

3. $\dfrac{3x+5}{x+1}=\dfrac{4x+8}{3x+3}+\dfrac{10x+1}{6x+3}.$ **4.** $\dfrac{6x+8}{2x+1}-\dfrac{2x+38}{x+12}=1$

5. $\dfrac{x+18}{x-2}-\dfrac{27-3x}{3x-19}=2$ **6.** $\dfrac{x-b}{x-a}-\dfrac{x-a}{x-b}=\dfrac{2(a-b)}{x-(a+b)}.$

7. $\dfrac{x+2a}{2b-x}+\dfrac{x-2a}{2b+x}+\dfrac{4ab}{x^2-4b^2}=0$

8. $\dfrac{(x-a)(x-b)}{x-a-b}=\dfrac{(x-c)(x-d)}{x-c-d}.$

9. $\frac{1}{x^2+3x+2}+\frac{2x}{x^2+4x+3}+\frac{1}{x^2+5x+6}=14-\frac{60+4x}{x+3}$.

10. $\frac{a+x}{a^2+ax+x^2}+\frac{a-x}{a^2-ax+x^2}=\frac{3a}{x(a^4+a^2x^2+x^4)}$.

11. $\frac{x}{x-2}+\frac{x-9}{x-7}=\frac{x+1}{x-1}+\frac{x-8}{x-6}$.

12. $\frac{1}{(x+a)^2-b^2}+\frac{1}{(x+b)^2-a^2}=\frac{1}{x^2-(a+b)^2}+\frac{1}{x^2-(a-b)^2}$.

13. $\frac{3x^2+5x+8}{5x^2+6x+12}=\frac{3x+5}{5x+6}$. 14. $\frac{58x^2+87x+7}{87x^2+145x+11}=\frac{2x+3}{3x+5}$.

15. $\frac{a^2(a-2b)}{b(a-b)^2}\cdot x+\frac{2abc}{a-b}-\frac{ax}{b}=2cx-\frac{a^2b^2}{(a-b)^3}$.

16. $(x-23)^3+(x-27)^3=2(x-25)^3$

17. $\frac{4x-17}{9}-\frac{3\frac{2}{3}-22x}{33}=x-\frac{6}{x}\left(1-\frac{x^2}{54}\right)$.

18. $\left(\frac{x-2a}{x+2b}\right)^2=\frac{x-2a-2b}{x+2a+2b}$. 19. $\frac{x+19}{x+10}=\left(\frac{2x+33}{2x+24}\right)^2$.

20. $\left(\frac{x-a}{x+b}\right)^3=\frac{x-2a-b}{x+a+2b}$.

177. A simple equation cannot have more than one root. If terms containing the unknown quantity be transferred to one side of the equation and those involving known quantities to the other side, every simple equation can ultimately by reduced to the form $ax=b$

Thus, to make the equation true, x must be equal to $\frac{b}{a}$ and to nothing else

Hence, a simple equation cannot have more than one root.

Otherwise Every simple equation is ultimately reducible to the form $ax=b$ Let this equation, if possible, have two different roots α and β

Thus, we must have $\left.\begin{aligned} a\alpha&=b \\ a\beta&=b \end{aligned}\right\}$ and also

Hence, by subtraction, $a(\alpha-\beta)=0$

But this is impossible because a is not zero and by supposition $\alpha-\beta$ also is not zero

Thus, a simple equation cannot have more than one root

178. Two exceptions in the solution of a Simple Equation.

(1) If a simple equation reduces to the form

$$0\times x=0, \qquad i\,e \qquad 0=0$$

Evidently *the equation is identically true and has therefore, any number of roots*

Example. The equation

$$x+2=\frac{x}{2}+\frac{x+4}{2}$$

gives, on transposition,

$$(1-\tfrac{1}{2}-\tfrac{1}{2})x=\tfrac{4}{2}-2,$$

$$\text{or.}\quad 0\times x=0,$$

$$\text{or,}\qquad 0=0$$

The equation is, therefore, an identity and is true for every value of x

(2) The equation

$$\left(\frac{x+5}{3}\right)=\frac{x+4}{2}-\frac{x-4}{6}$$

leads on simplification and transposition to

$$(\tfrac{1}{3}-\tfrac{1}{2}+\tfrac{1}{6})x=\tfrac{4}{2}+\tfrac{4}{6}-\tfrac{5}{3}$$

$$\text{or,}\quad 0\times x=1,$$

$$\text{or.}\quad 0=1,\quad \text{which is absurd}$$

This equation is, therefore, absurd and has consequently no root

Generally, *if a simple equation reduces to the form* $0\times x=b$, where b is *not* zero *the equation is absurd and cannot, therefore, have any root*

II. Problems leading to Simple Equations.

179. The general process of solving such problems has been explained in Chapter XVII We shall in the present section consider a few problems of a harder type than those treated of previously

The following examples will serve as further illustrations

Example 1. At what time between 1 o'clock and 2 o'clock is there exactly one minute-division between the hands of a clock?

Suppose it is x minutes past one when the hands are one minute-division apart from each other

Then, at the required instant the minute-hand is at a distance of x minute-divisions from the 12 o'clock mark, and since the minute-hand moves twelve times as fast as the hour-hand, the hour-hand moves over $\frac{x}{12}$ths of a minute-division whilst the minute-hand moves over x minute-divisions, therefore at the required instant the hour-hand is at a distance of $\left(5+\frac{x}{12}\right)$ minute-divisions from the 12 o'clock mark

Hence, as the minute-hand is at the required instant one minute-division apart from the hour-hand, we must have $x=\left(5+\frac{x}{12}\right)\pm 1.$

The upper sign being taken when the minute-hand is ahead of the hour-hand, and the lower when behind it,

$$\therefore \quad \tfrac{11}{12}x=5\pm 1=6, \quad \text{or, } 4$$

$$\therefore \quad x=\tfrac{72}{11}=6\tfrac{6}{11}, \quad \text{or, } =\tfrac{48}{11}=4\tfrac{4}{11}$$

Thus the hands are one minute-division apart at $4\frac{4}{11}$ or $6\frac{6}{11}$ minutes past one

Example 2. The distance from a place P to another place Q is $3\frac{1}{2}$ miles Two persons, A and B, start together from P to go to Q, the former by carriage which travels at the rate of 6 miles an hour, the latter walking at the rate of 3 miles an hour If A remains at Q for 15 minutes, and then returns by the carriage to P, find where he will meet B

[C U Entr Paper, 1882]

Let x miles be the distance of the place of meeting from P.

Then, during the time that B travels x miles, A finishes the journey, remains at Q for 15 minutes, and then travels back $(3\frac{1}{2}-x)$ miles

Now, the time in which A does all these

$$=\left(\frac{3\frac{1}{2}}{6}+\frac{1}{4}+\frac{3\frac{1}{2}-x}{6}\right)\text{ hours;}$$

and the time in which B travels x miles $=\frac{x}{3}$ hours,

$$\therefore \qquad \frac{3\frac{1}{2}}{6}+\frac{1}{4}+\frac{3\frac{1}{2}-x}{6}=\frac{x}{3},$$

$$\text{or,} \qquad 7+3+(7-2x)=4x,$$

$$\therefore \quad 6x=17, \qquad x=2\tfrac{5}{6}$$

Thus A will meet B at a distance of $2\frac{5}{6}$ miles from P

Example 3. A landlord let his farm for £10 a year in money, and a corn-rent When corn sold at 10s a bushel he received at the rate of 10 shillings an acre for his land, but when it sold at 13s 6d a bushel 13 shillings an acre Of how many bushels did the corn-rent consist?

Let $x=$ the number of bushels the corn-rent consisted of

Then when corn sold at 10s a bushel, the annual income was £10 + 10x shillings or $(200+10x)$ shillings, hence, as the income in this case was in the rate of 10s an acre, the number of acres must evidently be $\frac{200+10x}{10}$, or, $20+x$

In the second case (*i.e*, when corn sold at 13s 6d a bushel) the annual income amounted to £10 + $(13\frac{1}{2})x$ shillings, or, $\frac{400+27x}{2}$ shillings, but now the income was at the rate of 13s an acre Hence the number of acres must also be equal to $\frac{400+27x}{26}$.

$$\text{Hence,} \qquad 20+x=\frac{400+27x}{26},$$

$$\text{or,} \qquad 520+26x=400+27x; \qquad \therefore \; x=120$$

Thus the corn-rent consisted of 120 bushels

Example 4. A hare is eighty of her own leaps before a greyhound, she takes three leaps for every two that he takes, but he covers as much ground in one leap as she does in two How many leaps will the hare have taken before she is caught?

Let $3x=$ the number of leaps the hare takes

Then $2x=$ the number of leaps the greyhound takes in the same time

The distance of the place where the hare is caught from the first position of the greyhound $=(80+3x)$ leaps of the hare and is also $=2x$ leaps of the greyhound.

But, 1 leap of the greyhound being equal to 2 leaps of the hare. $2x$ leaps of the greyhound $=4x$ leaps of the hare,

$$\therefore\quad 80+3x=4x; \qquad x=80$$

Hence, the number of leaps which the hare takes before she is caught $=3\times 80=240$

Example 5. A banker has two kinds of money, silver and gold, and a pieces of silver or b pieces of gold, make up the same sum s A person comes and wishes to be paid the sum s with c pieces of money; how many of each must the banker give him?

Let $x=$ the number of silver pieces required,

then $c-x=$ „ „ „ gold „ „ .

$$\left.\begin{array}{l}\text{The value of one piece of silver} = \dfrac{s}{a}\\[2ex] \text{and that of one piece of gold} = \dfrac{s}{b}\end{array}\right\}$$

Hence, since by supposition x pieces of silver and $(c-x)$ pieces of gold are together equal in value to s, we must have

$$s=x\frac{s}{a}+(c-x)\frac{s}{b};$$

$$\therefore\quad 1=\frac{x}{a}+\frac{c-x}{b},$$

$$\text{or.}\quad x\left(\frac{1}{b}-\frac{1}{a}\right)=\frac{c}{b}-1;$$

$$x=\frac{a(c-b)}{a-b},$$

$$\text{and}\qquad c-x=c-\frac{a(c-b)}{a-b}=\frac{b(a-c)}{a-b}.$$

Thus, $\dfrac{a(c-b)}{a-b}$ pieces of silver and $\dfrac{b(a-c)}{a-b}$ pieces of gold will be required.

Example 6. AB is a railway 220 miles long, and three trains (P, Q, R) travel upon it at the rate of 25, 20 and 30 miles per hour respectively, P and Q leave A at 7 A.M and 8-15 A M, respectively, and R leaves B at 10-30 A M When and where will P be equidistant from Q and R?

A Q P R B

Let P, Q R, as in the figure, be the respective positions of the trains at the instant when P is equidistant from Q and R

Let this happen x hours after R has left B, i e, x hours after 10-30 A M

Then since P left A $3\frac{1}{2}$ hours before 10-30 A M, it has evidently been travelling for $(3\frac{1}{2}+x)$ hours up to the instant in question

Hence, clearly $AP=(3\frac{1}{2}+x)\,25$ miles.

and $AQ=(2\frac{1}{4}+x)\,20$ miles,

also $BR=30x$ miles

Hence,
$$PQ=AP-AQ$$
$$=\{(3\tfrac{1}{2}+x)\,25-(2\tfrac{1}{4}+x).20\}\text{ miles},$$

and
$$PR=AB-AP-BR$$
$$=\{220-(3\tfrac{1}{2}+x)\,25-30x\}\text{ miles}$$

But
$$PQ=PR,$$
$$(3\tfrac{1}{2}+x)\,25-(2\tfrac{1}{4}+x)\,20=220-(3\tfrac{1}{2}+x)\,25-30x,$$
$$50(3\tfrac{1}{2}+x)-(2\tfrac{1}{4}+x)\,20=220-30x.$$
$$60x=220-175+45=90,$$
$$x=1\tfrac{1}{2}$$

Thus, P will be equally distant from Q and R at $1\frac{1}{2}$ hours after 10-30 A M i e, at 12 A M

Also as P left A at 7 A M, its distance from A at that instant will be 5×25, or, 125 miles

Example 7. Two passengers have together 5 cwt of luggage and are charged for the excess above the weight allowed 5*s* 2*d* and 9*s* 10*d* respectively, but if the luggage had all belonged to one of them he would have been charged 19*s* 2*d* How much luggage is each passenger allowed to carry free of charge? And how much luggage had each passenger,

[C U Entr Paper, 1877]

Let x cwt = weight of luggage that each passenger is allowed to carry free of charge

Then (5*s* 2*d*)+(9*s* 10*d*) = charge for $(5-2x)$ cwt

$$\frac{15\times 12}{5-2x}\,d=\text{charge for 1 cwt}$$

Also, $19s\ 2d$ = charge for $(5-x)$ cwt,

$\therefore$ $\dfrac{230}{5-x}d$ = charge for 1 cwt

Hence, $\dfrac{15\times12}{5-2x}=\dfrac{230}{5-x}$;

$$18(5-x)=23(5-2x),$$

or, $28x=115-90=25$, $\therefore$ $x=\frac{25}{28}$,

i e, weight of luggage allowed $=\frac{25}{28}$ cwt $=\frac{25}{28}\times4\times28$ lbs. $=100$ lbs

Now, charge for 1 cwt

$$=\frac{230}{5-x}d=\frac{230}{5-\frac{25}{28}}d=\frac{230\times28}{5\times23}d=56d$$

And since charge for excess luggage of the first passenger $=5s\ 2d=62d$, and charge for excess luggage of the second passenger $=9s\ 10d=118d$,

$\therefore$ weight of excess luggage of the first passenger $=\frac{62}{56}$ cwt $=\frac{62}{56}\times4\times28$ lbs $=124$ lbs,

and weight of excess luggage of the second passenger $=\frac{118}{56}$ cwt $=\frac{118}{56}\times4\times28$ lbs $=236$ lbs.

Hence, whole luggage of the first passenger $=(100+124)$ lbs $=224$ lbs,

and whole luggage of the second passenger $=(100+236)$ lbs $=336$ lbs

Example 8. A person buys some tea at 3 shillings a pound and some at 5 shillings a pound, he wishes to mix them; so that by selling the mixture at $3s\ 8d$ a pound, he may gain 10 per cent on each pound sold Find how many pounds of the inferior tea he must mix with each pound of the superior

Suppose x lbs of the inferior tea are mixed with each pound of the superior,

the price of x lbs of the inferior tea and one pound of the superior $=(3x+5)$ shillings;

$\therefore$ the average cost per pound $=\dfrac{3x+5}{x+1}$ shillings

But by selling the mixture at $3\frac{2}{3}s$ a pound, he *gains* 10 *per cent* on each pound i e, realises $110s$ for every $100s$, or $\frac{11}{10}s$ for every shilling.

Hence, $3\frac{2}{3}s = \frac{11}{10}$ of the cost per pound;

$$3\frac{2}{3}=\frac{11}{10}\times\frac{3x+5}{x+1},$$

or, $$\frac{11}{3}=\frac{11}{10}\times\frac{3x+5}{x+1};$$

$$\therefore \quad 10(x+1)=3(3x+5),$$

$$\therefore \quad x=5$$

Thus, 5 ponnds of the inferior tea must be mixed with each pound of the superior

Example 9. An officer can form his men into a hollow square 5 deep, and also into a hollow square 6 deep, but the front in the latter formation contains 4 men fewer than in the former, find the number of men [C U Entr Paper, 1887]

[A number of men are said to be arranged in a *solid* square when they are arranged in parallel rows and the number of rows is equal to the number of men in each row The following diagram, in which $A_1, B_1, C_1,$ &c represent men, will give the student a correct notion of such arrangement

$$\begin{array}{cccccccc}
A_1 & B_1 & C_1 & D_1 & E_1 & F_1 & G_1 & H_1 \\
A_2 & B_2 & C_2 & D_2 & E_2 & F_2 & G_2 & H_2 \\
A_3 & B_3 & C_3 & D_3 & E_3 & F_3 & G_3 & H_3 \\
A_4 & B_4 & C_4 & D_4 & E_4 & F_4 & G_4 & H_4 \\
A_5 & B_5 & C_5 & D_5 & E_5 & F_5 & G_5 & H_5 \\
A_6 & B_6 & C_6 & D_6 & E_6 & F_6 & G_6 & H_6 \\
A_7 & B_7 & C_7 & D_7 & E_7 & F_7 & G_7 & H_7 \\
A_8 & B_8 & C_8 & D_8 & E_8 & F_8 & G_8 & H_8
\end{array}$$

The diagram represents an arrangement in which there are 8 rows, each containing 8 men This is a *solid* square If the square $C_3F_3F_6C_6$ be removed from inside, the

remainder will be a *hollow* square *two deep* having 8 men in the front rank; if, however, the square $D_4\ E_4\ E_5\ D_5$ be removed, the remainder will be a *hollow* square *three deep*, having the same 8 men in the front rank

Hence, the number of men in a *hollow* square *two deep* having x men in the front rank$=x^2-(x-4)^2$; in one *three deep* $=x^2-(x-6)^2$, and so on, thus the number of men in a hollow square n deep having x men in the front row $=x^2-(x-2n)^2$.]

Let x=the number of men in the front row of the first arrangement

Then $x-4$=the number of men in the front row of the second arrangement

Hence, the number of men in the first square

$$=x^2-(x-10)^2 \qquad (1)$$

and the number of men in the second square

$$=(x-4)^2-\{(x-4)-12\}^2$$

But the men that form the first square are exactly those that form the second,

$$\therefore \quad x^2-(x-10)^2=(x-4)^2-\{(x-4)-12\}^2,$$

or, $$20x-100=24(x-4)-144,$$

$$4x=144+96-100=140,$$

$$\therefore \quad x=35.$$

Hence, from (1) the total number of men

$$=(35)^2-(25)^2=60\times10=600$$

EXERCISE 95.

1. Find the time between 3 and 4 o'clock, when the two hands of a watch are coincident

2. At what time are the hands of a watch together between 5 and 6 o'clock? [C U Entr Paper, 1886.]

3. Find the respective times between 7 and 8 o'clock when the hour and minute-hands of a watch are (i) exactly opposite to each other, (ii) at right angles to each other, (iii) coincident

4. What is the *first* hour after 6 o'clock at which the two hands of a watch are (i) directly opposite, (ii) at right angles to each other?

5. Two men set out at the same time to walk, one from A to B, and the other from B to A, a distance of a miles The former walks at the rate of p miles and the latter at the rate of q miles an hour, at what distance from A will they meet?

6. Two persons walk at the rate of 5 and 6 miles an hour respectively They set out to meet each other from two places 22 miles apart Having passed each other once, find the place of their *second* meeting, supposing them to continue their journey between the two places Also find the time when the second meeting takes place

7. A man rides one-third of the distance from A to B at the rate of a miles per hour and the remainder at the rate of $2b$ miles per hour If he had travelled at a uniform rate of $3c$ miles per hour he could have ridden from A to B and back again in the same time

Prove that $\frac{2}{c} = \frac{1}{a} + \frac{1}{b}$. [C U Entr Paper 1889]

8. A and B start to run a race. At the end of 5 minutes, when A has run 900 yards and has outstripped B by 75 yards, he falls; but though he loses ground by the accident, and for the rest of the course makes 20 yards a minute less than before, he comes in only half a minute behind B. How long did the race last?

9. A person sets out to walk from a certain town, but when he has accomplished a quarter of his journey, he finds that if he continues at the same pace he will have gone only $\frac{5}{6}$ths of the whole distance when he ought to be at his destination He therefore increases his speed by a mile an hour, and arrives just in time Find the rate of walking

10. A tenant hired his farm for £80 a year in money and a corn-rent in rice When rice sold at £1 5*s* a bushel, he paid at the rate of £1 15*s* an acre for his land, when it sold at £1 10*s* a bushel, he paid at the rate of £2 an acre Find the number of bushels of rice in the rent

11. A footman who contracted for £8 a year and a livery suit, was turned away at the end of 7 months and received only £2 3*s* 4*d* and his livery What was its value?

12. A hare, 50 of her leaps before a greyhound, takes 4 leaps to the greyhound's three, but two of the greyhound's leaps are as much as three of the hare's How many must the greyhound take to catch the hare?

13. A greyhound spying a hare at a distance of 60 of his own leaps from him, pursues her, making 4 leaps for every 5 leaps of the hare, but he passes over as much ground in 3 leaps as the hare does in 4 How many leaps did each make during the whole course?

14. The St John's boat is ahead of the Caius by a distance equivalent to 30 strokes of the former The Johnians pull 4 strokes to 3 strokes of the Caius, but 2 of the latter are equivalent to 3 of the former. How many strokes must the Caius take to bump the St John's boat?

15. *A* and *B* find a purse with shillings in it *A* takes out two shillings and one-sixth of what remains, then *B* takes out three shillings and one-sixth of what remains, and then they find that they have taken out equal shares How many shillings were in the purse, and how many did each take?

16. A ship sails with a supply of biscuit for 60 days at a daily allowance of 1 pound a head, after being at sea 20 days she encounters a storm in which 5 men are washed overboard and damage sustained, that will cause a delay of 24 days, and it is found that each man's allowance must be reduced to $\frac{5}{7}$ths of a pound Find the original number of the crew

17. If 19 lbs of gold weigh 18 lbs in water, and 10 lbs. of silver weigh 9 lbs in water, find the quantity of gold and silver in a mass of gold and silver weighing 106 lbs in air and 99 lbs in water

18. A person rows from Cambridge to Ely, a distance of 20 miles and back again in 10 hours, the stream flowing uniformly in the same direction all the time; and he finds that he can row in 2 miles against the stream in the same time that he rows 3 miles with it Find the time of his going and returning

19. A person passed $\frac{1}{6}$th of his age in childhood, $\frac{1}{12}$th in youth, $\frac{1}{7}$th$+5$ years in matrimony, he had then a son, whom he survived 4 years, and who reached only one-half the age of his father Find the son's age when he died

20. There are two bars of metal, the first containing 14 *oz* of silver and 6 of tin, the second containing 8 of silver and 12 of tin, how much must be taken from each to form a bar of 20 *oz* containing equal weights of silver and tin?

21. Divide £607 1*s* 8*d* into two sums, such that the simple interest of the greater sum for two years, at $3\frac{1}{2}$ per cent shall exceed that of the less for $2\frac{1}{2}$ years, at $3\frac{1}{4}$ per cent. by £18 16*s*

22. To remove four articles of furniture, I required for the 1st article two coolies, for the 2nd three, for the 3rd four, and for the 4th five After giving the 1st set of men one group of pice and one pice more, to the 2nd set an equal group and four pice more, to the 3rd an equal group and five pice more and to the 4th an equal group and nine pice more, I found that each man of the 3rd and 4th sets had received the same number of pice. How many pice were there in each group, how many pice did each man receive, and how many pice did I distribute?

23. Fifteen current guineas should weigh 4 ounces, but a parcel of light gold being weighed and counted, was found to contain 9 more guineas than was supposed from the weight, and a part of the whole, exceeding the half by 10 guineas and a half, was found to be $1\frac{1}{3}$ *oz* deficient in weight What was the number of guineas in the parcel?

24. A silversmith received in payment for a certain weight of wrought plate, the price of which was £10, the same weight of unwrought plate, and £3 15*s* besides At another time he exchanged 12 *oz* of wrought plate of the same workmanship as before for 8 *oz* of unwrought (for which he allowed the same price as before), and £2 16*s* in money What was the price of wrought plate per ounce, and the weight of the first sold?

25. Two passengers are charged for excess of luggage 2*s* 10*d* and 7*s* 6*d* respectively, had the luggage all belonged to one of them, he would have been charged for excess 14*s* 6*d*; how much would they have been changed if none had been allowed free?

26. How many bundles of hay at Rs 5 per thousand must a *ghaswala* mix with 5600 bundles at Rs 6 per thousand, in order that he may gain 20 per cent by selling the whole at 11 *as* per hundred? [C U Entr Paper, 1875]

27. A boy buys a certain number of oranges at 3 for 2*d* and one-third of that number at 2 for 1 *d*; at what price must he sell them to get 20 per cent profit, if his profit be 5*s* 4*d*, find the number bought [C U Entr Paper, 1885.]

28. From each of a number of foreign gold coins a person filed a fifth part, and had passed two-thirds of them, when the rest were seized as light coins except one, with which the man decamped, having lost upon the whole half as much as he had gained before How many coins were there at first?

29. Find a number of three digits, each greater by unity than that which follows it, so that its excess above one-fourth of the number formed by inverting the digits shall be 36 times the sum of the digits

30. A number of troops being formed into a solid square, it was found there were 60 over, but when formed into a column with 5 men more in front than before and 3 less in depth, there was just one man wanting to complete it Find the number

31. An officer can form the men of his regiment into a hollow square 10 deep The number of men in the regiment is 2800 Find the number of men in the front of the hollow square

32. A company of men is formed into a hollow square 4 deep and also into a hollow square 8 deep, the front in the latter formation contains 19 men fewer than that in the former formation; find the number of men

33. A detachment from an army was marching in regular column with 5 men more in depth than in front, but upon the enemy coming in sight the front was increased by 845 men, and by this movement the detachment was drawn up in five lines Find the number of men in the detachment

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CHAPTER XXVII

HARDER SIMULTANEOUS EQUATIONS AND PROBLEMS

180. The process of solving easy simultaneous equations in two variables has already been explained in Chapter XVIII We propose now to consider the subject more fully

181. Method of Cross Multiplication.

If $a_1x+b_1y+c_1z=0$, and $a_2x+b_2y+c_2z=0$,† to prove that

$$\frac{x}{b_1c_2-b_2c_1}=\frac{y}{c_1a_2-c_2a_1}=\frac{z}{a_1b_2-a_2b_1}.$$

Multiplying the 1st equation by c_2, and the 2nd by c_1, we have

$$a_1c_2x+b_1c_2y+c_1c_2z=0,$$
$$\text{and}\quad a_2c_1x+b_2c_1y+c_2c_1z=0$$

Hence, by subtraction,

$$(c_1a_2-c_2a_1)x+(b_2c_1-b_1c_2)y=0,$$
$$\therefore\quad (c_1a_2-c_2a_1)x=(b_1c_2-b_2c_1)y;$$
$$\therefore\quad \frac{x}{b_1c_2-b_2c_1}=\frac{y}{c_1a_2-c_2a_1}. \qquad (1)$$

Again, multiplying the 1st equation by a_2, and the 2nd by a_1, we have

$$a_1a_2x+b_1a_2y+c_1a_2z=0,$$
$$\text{and}\quad a_2a_1x+b_2a_1y+c_2a_1z=0$$

Hence, by subtraction,

$$(a_1b_2-a_2b_1)y+(c_2a_1-c_1a_2)z=0,$$
$$\therefore\quad (a_1b_2-a_2b_1)y=(c_1a_2-c_2a_1)z,$$
$$\therefore\quad \frac{y}{c_1a_2-c_2a_1}=\frac{z}{a_1b_2-a_2b_1}. \qquad (2)$$

† It is necessary to point out to the student the notation here used. The letter a_1 is as different from a_2 as c is from d, or as any letter of the alphabet from any other; a similar remark applies to the pairs of letters (b_1, b_2) and (c_1, c_2). But it is very convenient as an aid to memory to use the same letter with different suffixes to denote corresponding co-efficients in different equations; thus whilst a_1 denotes the co-efficient of x in the 1st equation, a_2 denotes the co-efficient of x in the 2nd equation; and precisely a similar meaning is attached to the letters b_1, b_2 and c_1, c_2. Sometimes however letters with accents serve the same purpose; thus if a, b, c denote the co-efficients of x, y, z in one equation the corresponding co-efficients in a second equation are denoted by a', b', c'; in a third equation by a'', b'', c''; and so on.

Hence, from (1) and (2),

$$\frac{x}{b_1c_2-b_2c_1}=\frac{y}{c_1a_2-c_2a_1}=\frac{z}{a_1b_2-a_2b_1}.$$

Note. *This result can be easily remembered, writing down the equations one above the other,*

$$\left.\begin{aligned}a_1x+b_1y+c_1z=0\\a_2x+b_2y+c_2z=0\end{aligned}\right\},\ \text{we find that}$$

(i) the quantity under x=co-efficient of y in the 1st equation $\times$ co-efficient of z in the 2nd **minus** *co-efficient of y in the 2nd$\times$co-efficient of z in the 1st,*

(ii) the quantity under y=co-efficient of z in the 1st equation $\times$ co-efficient of x in the second **minus** *co-efficient of z in the 2nd$\times$co-efficient of x in the 1st,*

(iii) the quantity under z=co-efficient of x in the 1st equation$\times$ co-efficient of y in the 2nd **minus** *co-efficient of x in the 2nd$\times$co-efficient of y in the 1st.*

Cor. In the above equations if we put $z=1$, we have

$$\frac{x}{b_1c_2-b_2c_1}=\frac{y}{c_1a_2-c_2a_1}=\frac{1}{a_1b_2-a_2b_1},$$

which gives the solution of the equations

$$\text{and}\qquad\left.\begin{aligned}a_1x+b_1y+c_1=0\\a_2x+b_2y+c_2=0\end{aligned}\right\}$$

Note *The above results should be thoroughly committed to memory, as ready applications of them will enable the student to solve with neatness not only simple equations involving* ***two*** *unknown quantities, but also a certain class of equations involving* ***three*** *unknown quantities The following examples are intended for illustration*

Example 1. Solve $\left.\begin{aligned}3x-5y+9=0\\5x-3y-1=0\end{aligned}\right\}$

Here $a_1=3,\quad b_1=-5,\quad c_1=\ \ 9,$
$\qquad a_2=5,\quad b_2=-3,\quad c_2=-1.$

Hence, we must have

$$\frac{y}{(-5)(-1)-(-3)9}=\frac{y}{9\times5-(-1)3}=\frac{1}{3(-3)-5(-5)}$$

or, $\frac{x}{5+27}=\frac{y}{45+3}=\frac{1}{-9+25}$,

or, $\frac{x}{32}=\frac{y}{48}=\frac{1}{16}$;

$\therefore$ $x=\frac{32}{16}=2$, and $y=\frac{48}{16}=3$

Thus, we have $x=2$, and $y=3$

Example 2. Solve
$$\left.\begin{aligned} -7x+8y&=9 \quad (1)\\ 5x-4y&=-3 \quad (2)\end{aligned}\right\}$$

From (1), $-7x+8y-9=0$
From (2), $5x-4y+3=0$

Hence,

$$\frac{x}{8\times3-(-4)(-9)}=\frac{y}{(-9)5-3(-7)}=\frac{1}{(-7)(-4)-5\times8},$$

or, $\frac{x}{24-36}=\frac{y}{-45+21}=\frac{1}{28-40}$,

or, $\frac{x}{-12}=\frac{y}{-24}=\frac{1}{-12}$;

$x=\frac{-12}{-12}=1$, and $y=\frac{-24}{-12}=2$

Thus, we have $x=1$, and $y=2$

Example 3. Solve
$$\left.\begin{aligned} (x+7)(y-3)+7&=(y+3)(x-1)+5 \quad (1)\\ 5x-11y+35&=0 \quad (2)\end{aligned}\right\}$$

[C U Entr Paper, 1888]

From (1), $xy+7y-3x-14=xy+3x-y+2$,

$6x-8y+16=0$,

$\therefore$ $3x-4y+8=0$

also $5x-11y+35=0$

Hence,

$$\frac{x}{(-4)35-(-11)8}=\frac{y}{8\times5-35\times3}=\frac{1}{3(-11)-5(-4)},$$

or, $\frac{x}{-140+88}=\frac{y}{40-105}=\frac{1}{-33+20}$,

or, $\frac{x}{-52}=\frac{y}{-65}=\frac{1}{-13}$,

Hence, $x=4$, and $y=5$.

Example 4. Solve
$$\left.\begin{aligned} 2x-3y+4z&=0 \quad \ldots \quad (1)\\ 7x+2y-6z&=0 \quad \ldots \quad (2)\\ 4x+3y+z&=37 \quad \ldots \quad (3)\end{aligned}\right\}$$

From (1) and (2), we have

$$\frac{x}{(-3)(-6)-2\times4}=\frac{y}{4\times7-(-6)2}=\frac{z}{2\times2-7(-3)},$$

or, $$\frac{x}{10}=\frac{y}{40}=\frac{z}{25},$$

or, $$\frac{x}{2}=\frac{y}{8}=\frac{z}{5}.$$

Now, let k denote the common value of these fractions which is at present unknown

Then we have $$\frac{x}{2}=\frac{y}{8}=\frac{z}{5}=k,$$

$$\therefore\ x=2k,\quad y=8k,\ z=5k \quad \ldots \quad (A)$$

Substituting these values of x, y, z in (3), we have

$$k(8+24+5)=37,$$

$$\text{or,}\quad 37k=37,\quad \therefore\ k=1$$

Hence, from (A), $x=2$, $y=8$, $z=5$

Example 5. Solve
$$\left.\begin{aligned} x+6y&=5z \quad \ldots \quad (1)\\ 7x+z&=6y \quad \ldots \quad (2)\\ 5x+6y-4z&=24 \quad\quad (3)\end{aligned}\right\}$$

From (1), $\left.\begin{aligned} x+6y-5z&=0\\ 7x-6y+z&=0\end{aligned}\right\}$
From (2),

Hence,

$$\frac{x}{6\times1-(-6)(-5)}=\frac{y}{(-5)7-1\times1}=\frac{z}{1(-6)-7\times6},$$

or, $$\frac{x}{6-30}=\frac{y}{-35-1}=\frac{z}{-6-42},$$

or, $$\frac{x}{-24}=\frac{y}{-36}=\frac{z}{-48};$$

$$\therefore\quad \frac{x}{2}=\frac{y}{3}=\frac{z}{4}.$$ [Multiplying each fraction by -12]

Supposing each of these fractions $=k$, we have

$$x=2k,\ y=3k,\ z=4k \quad \ldots \quad (A)$$

Substituting these values of x, y, z in (3), we have

$$k(10+18-16)=24,$$

$$\text{or,} \quad 12k=24; \qquad k=2.$$

Hence, from (A), $x=4$, $y=6$, $z=8$

EXERCISE 96.

Solve the following equations

1. $\left.\begin{aligned} 2x+3y-8 &= 0 \\ 3x-4y+5 &= 0 \end{aligned}\right\}$ **2.** $\left.\begin{aligned} 3x-5y+9 &= 0 \\ 5x+2y-16 &= 0 \end{aligned}\right\}$

3. $\left.\begin{aligned} 4x-5y+8 &= 0 \\ 2x-3y+6 &= 0 \end{aligned}\right\}$ **4.** $\left.\begin{aligned} -3x+2y+2 &= 0 \\ 5x-3y-5 &= 0 \end{aligned}\right\}$

5. $\left.\begin{aligned} 6x-7y+12 &= 0 \\ -7x+4y+11 &= 0 \end{aligned}\right\}$ **6.** $\left.\begin{aligned} 7x-8y &= -14 \\ 5x-3y &= 9 \end{aligned}\right\}$

7. $\left.\begin{aligned} -6x+5y+2 &= 0 \\ 13x-9y &= 19 \end{aligned}\right\}$ **8.** $\left.\begin{aligned} -7x+5y+11 &= 0 \\ 8x-5y &= 19 \end{aligned}\right\}$

9. $\left.\begin{aligned} 4x-11y+6 &= 0 \\ 9x-13y &= 10 \end{aligned}\right\}$ **10.** $\left.\begin{aligned} 8x-7y &= 19 \\ 10x-9y &= 23 \end{aligned}\right\}$

11. $\left.\begin{aligned} -12x+17y+16 &= 0 \\ 9x-13y &= 11 \end{aligned}\right\}$ **12.** $\left.\begin{aligned} 14x-11y+18 &= 0 \\ 11x-7y+1 &= 0 \end{aligned}\right\}$

13. $\left.\begin{aligned} 17x-7y &= 52 \\ 3x &= 2y \end{aligned}\right\}$ **14.** $\left.\begin{aligned} 9x+5y &= 124 \\ 7x &= 3y \end{aligned}\right\}$

$\left[\text{From the 2nd equation } \dfrac{x}{2}=\dfrac{y}{3}=k \text{ (suppose)}\right]$

15. $\left.\begin{aligned} 15x+7y &= 246 \\ 9x &= 4y \end{aligned}\right\}$ **16.** $\left.\begin{aligned} 9x &= 8y \\ 10x+23y-287 &= 0 \end{aligned}\right\}$

17. $\left.\begin{aligned} 4x-3y &= 0 \\ 7x-11y+92 &= 0 \end{aligned}\right\}$ **18.** $\left.\begin{aligned} 4x-7y &= 0 \\ 10x-9y-102 &= 0 \end{aligned}\right\}$

19. $\left.\begin{aligned} 13x-12y+15 &= 0 \\ 8x-7y &= 0 \end{aligned}\right\}$ **20.** $\left.\begin{aligned} 11x-10y+82 &= 0 \\ 14x-9y &= 0 \end{aligned}\right\}$

21. $\left.\begin{array}{l}\frac{1}{3}(x+y)+\frac{1}{4}(x-y)=59 \\ 5x-33y \qquad = 0\end{array}\right\}$ **22.** $\left.\begin{array}{l}\dfrac{4x+5y}{40} = x-y \\ \dfrac{2x-y}{3}+2y=20\end{array}\right\}$

23. $\left.\begin{array}{l}y(3+x)=x(7+y) \\ 4x+9 = 5y-14\end{array}\right\}$ **24.** $\left.\begin{array}{l}\dfrac{4y-6}{x+y} = 2 \\ \dfrac{8x-5}{y-x} = 9\end{array}\right\}$

25. $\left.\begin{array}{l}(x+5)(y+7)=(x+1)(y-9)+112 \\ 2x+10 = 3y+1\end{array}\right\}$

26. $\left.\begin{array}{l}4x-5y+2z=0 \\ 2x-7y+4z=0 \\ x+y+z=6\end{array}\right\}$ **27.** $\left.\begin{array}{l}5x+6y+8z=0 \\ 3x+4y+6z=0 \\ x+5y+16z=3\end{array}\right\}$

28. $\left.\begin{array}{l}2x-7y+11z=0 \\ 6x-8y+7z=0 \\ 3x+4y+5z=35\end{array}\right\}$ **29.** $\left.\begin{array}{l}7x+3y-8z=0 \\ 5x-7y+8z=0 \\ 3x+5y+7z=64\end{array}\right\}$

30. $\left.\begin{array}{l}x-2y+z=0 \\ 9x-8y+3z=0 \\ 2x+3y+5z=36\end{array}\right\}$ **31.** $\left.\begin{array}{l}2(4x+9y)=7(2y+z) \\ 7(x+2y)=8(y+z) \\ 3x+4y+5z=38\end{array}\right\}$

[C U Entr Paper, 1887]

32. $\left.\begin{array}{l}4(x+y)=3(2z-y) \\ 5(x-2y)=3(2y-3z) \\ 6(x-2)+7(y-3)+8(z-4)=67\end{array}\right\}$

33. $\left.\begin{array}{l}5x=2y,\ 7y=5z \\ 4x+5y+6z=150\end{array}\right\}$ **34.** $\left.\begin{array}{l}15x=10y=6z \\ 7x+8y+9z=332\end{array}\right\}$

35. $\left.\begin{array}{l}4x-13y+8z=0 \\ 7x+6y-9z=0 \\ \dfrac{5}{x}+\dfrac{8}{y}+\dfrac{15}{z}=6\frac{2}{3}\end{array}\right\}$

182. Equations of the form $a_1x+b_1y+c_1z=d_1$, $a_2x+b_2y+c_2z=d_2$, $a_3x+b_3y+c_3z=d_3$.

Multiply the first equation by c_2 and the 2nd by c_1; then by subtraction, we have

$$(a_1c_2-a_2c_1)x+(b_1c_2-b_2c_1)y=d_1c_2-d_2c_1 \quad \ldots \quad (1)$$

Similarly multiplying the first equation by c_3 and the 3rd by c_1, we have

$$(a_1c_3-a_3c_1)x+(b_1c_3-b_3c_1)y=d_1c_3-d_3c_1. \quad \ldots \quad (2)$$

Now, from (1) and (2), the value of x and y can be at once found by cross multiplication Then substituting the values of x and y thus found in any of the given equations, the value of z will be obtained

Otherwise

Multiply the 1st equation by d_2 and the 2nd by d_1, then by subtraction, we have

$$(a_1d_2-a_2d_1)x+(b_1d_2-b_2d_1)y+(c_1d_2-c_2d_1)z=0 \qquad (\alpha)$$

Similarly, multiplying the 1st equation by d_3 and the 3rd by d_1, we have

$$(a_1d_3-a_3d_1)x+(b_1d_3-b_3d_1)y+(c_1d_3-c_3d_1)z=0 \qquad (\beta)$$

Now evidently (α) and (β) together with any one of the given equations form a group which can be easily solved by the method illustrated in the last article

Example 1. Solve

$$\left.\begin{aligned} 4x-3y+2z&=40 \quad &(1)\\ 5x+9y-7z&=47 \quad &(2)\\ 9x+8y-3z&=97 \quad &(3)\end{aligned}\right\}$$

Multiplying (1) by 7, and (2) by 2, we have

$$\left.\begin{aligned} 28x-21y+14z&=280\\ \text{and}\quad 10x+18y-14z&=94\end{aligned}\right\}$$

Hence, by addition, $38x-3y=374$ (4)

Again, multiplying (1) by 3, and (3) by 2, we have

$$\left.\begin{aligned} 12x-9y+6z&=120\\ \text{and}\quad 18x+16y-6z&=194\end{aligned}\right\}.$$

Hence, by addition, $30x+7y=314$ (5)

Now, from (4) and (5), we have

$$\left.\begin{aligned} 38x-3y-374&=0\\ \text{and}\quad 30x+7y-314&=0\end{aligned}\right\}$$

Hence,

$$\frac{x}{3\times 314-7(-374)}=\frac{y}{(-374)30-(-314)38}=\frac{1}{38\times 7-30(-3)},$$

or, $$\frac{x}{942+2618}=\frac{y}{-11220+11932}=\frac{1}{266+90},$$

or, $$\frac{x}{3560}=\frac{y}{712}=\frac{1}{356}.$$

Therefore, $x=10$, and $y=2$

Substituting these values of x and y in (1), we have

$$40-6+2z=40, \quad \text{whence } z=3$$

Thus, we have $x=10, \quad y=2, \quad z=3$

Example 2. Solve
$$\left.\begin{aligned} 2x-\ 4y+9z&=28 \quad (1)\\ 7x+\ 3y-5z&=\ 3 \quad (2)\\ 9x+10y-11z&=\ 4 \quad (3)\end{aligned}\right\}$$

Multiplying (1) by 3, and (2) by 4, we have

$$\left.\begin{aligned} 6x-12y+27z&=84\\ \text{and} \qquad 28x+12y-20z&=12\end{aligned}\right\}$$

Hence, by addition, $\qquad 34x+7z=96 \qquad (4)$

Again, multiplying (2) by 10, and (3) by 3, we have

$$\left.\begin{aligned} 70x+30y-50z&=30\\ \text{and} \qquad 27x+30y-33z&=12\end{aligned}\right\}$$

Hence, by subtraction, $\qquad 43x-17z=18 \qquad (5)$

Now, from (4) and (5), we have

$$\left.\begin{aligned} 34x+\ 7z-96&=0\\ \text{and} \qquad 43x-17z-18&=0\end{aligned}\right\}$$

Hence,
$$\frac{x}{7(-18)-(-17)(-96)}=\frac{z}{(-96)43-(-18)34}$$
$$=\frac{1}{34(-17)-43\times 7},$$

or,
$$\frac{x}{-126-1632}=\frac{z}{-4128+612}=\frac{1}{-578-301},$$

or,
$$\frac{x}{-1758}=\frac{z}{-3516}=\frac{1}{-879}.$$

Therefore, $x=\dfrac{-1758}{-879}=2$, and $z=\dfrac{-3516}{-879}=4$

Substituting these values of x and z in (2), we have

$$14+3y-20=3,$$

whence $\qquad 3y=9$, and $\therefore\ y=3.$

Thus, we have $x=2, \quad y=3, \quad z=4$

Example 3. Solve
$$\left.\begin{aligned} 12x+9y-\ 7z&=2 \quad (1)\\ 8x-26y+\ 9z&=1 \quad (2)\\ 23x+21y-15z&=4 \quad (3)\end{aligned}\right\}$$

Multiplying (2) by 2, we have

$$16x-52y+18z=2,$$

also, $$12x+9y-7z=2 \qquad (1)$$

Hence, by subtraction, $4x-61y+25z=0$ (4)

Again, multiplying (1) by 2, we have

$$24x+18y-14z=4$$

also, $$23x+21y-15z=4. \qquad (3)$$

Hence, by subtraction, $x-3y+z=0$ (5)

Now, since we have $\left.\begin{aligned} 4x-61y+25z&=0, \quad (4)\\ \text{and} \quad x-3y+z&=0 \quad (5)\end{aligned}\right\}$

Therefore, by cross multiplication,

$$\frac{x}{-61+75}=\frac{y}{25-4}=\frac{z}{-12+61},$$

or, $$\frac{x}{14}=\frac{y}{21}=\frac{z}{49}, \text{ or, } \frac{x}{2}=\frac{y}{3}=\frac{z}{7}.$$

Supposing each of these fractions $=k$, we have

$$x=2k, \quad y=3k, \quad z=7k$$

Hence, from (1), $k(24+27-49)=2,$

or, $2k=2,$

$\therefore \quad k=1$

Therefore, $x=2, \quad y=3, \quad z=7.$

EXERCISE 97.

Solve the following equations

1. $\left.\begin{aligned} 2x-3y+5z&=11\\ 5x+2y-7z&=-12\\ -4x+3y+z&=5\end{aligned}\right\}$

2. $\left.\begin{aligned} 3x+2y+5z&=32\\ 2x+5y+3z&=31\\ 5x+3y+2z&=27\end{aligned}\right\}$

3. $\left.\begin{aligned} x+y-z&=1\\ 8x+3y-6z&=1\\ 3z-4x-y&=1\end{aligned}\right\}$

4. $\left.\begin{aligned} 2x+3y+4z&=29\\ 3x+2y+5z&=32\\ 4x+3y+2z&=25\end{aligned}\right\}$

5. $\left.\begin{aligned} 2x+3y+4z&=16\\ 3x+2y-5z&=8\\ 5x-6y+3z&=6\end{aligned}\right\}$

6. $\left.\begin{aligned} 4x-3y+2z&=8\\ 3x-4y+5z&=6\\ -6x+5y+7z&=-1\end{aligned}\right\}$

7. $\left.\begin{aligned} 8x-7y-5z&=1\\ -7x+5y+6z&=-1\\ 12x-8y-11z&=2\end{aligned}\right\}$

8. $\left.\begin{aligned} x+5y-4z&=5\\ 3x-2y+2z&=14\\ -10x+8y+z&=6\end{aligned}\right\}$

[C U Entr. Paper, 1867]

9. $\left.\begin{aligned} 2x+4y+5z&=49 \\ 3x+5y+6z&=64 \\ 4x+3y+4z&=55 \end{aligned}\right\}$

10. $\left.\begin{aligned} x+3y+5z&=10 \\ 3x+5y+7z&=14 \\ 5x+7y+8z&=15 \end{aligned}\right\}$

11. $\left.\begin{aligned} 12x+8y-11z&=-3 \\ 11x-13y-z&=2 \\ 8x+17y-12z&=-2 \end{aligned}\right\}$

12. $\left.\begin{aligned} 5x-4y+9z&=19 \\ 7x+6y-12z&=16 \\ -9x+8y+15z&=-13 \end{aligned}\right\}$

13. $\left.\begin{aligned} x-y-z&=-15 \\ y+x+2z&=40 \\ 4z-5x-6y&=-150 \end{aligned}\right\}$

[C U Entr Paper, 1886]

14. $\left.\begin{aligned} 2(x-y)&=3z-2 \\ x-3z&=3y-1 \\ 2x+3z&=4(1-y) \end{aligned}\right\}$

15. $\left.\begin{aligned} 3x+2y-z&=20 \\ 2x+3y+6z&=70 \\ x-y+6z&=41 \end{aligned}\right\}$

16. $\left.\begin{aligned} 4(y-x)&=5z-22 \\ 3z+4x&=6y+2 \\ z-3y&=14-10x \end{aligned}\right\}$

17. $\left.\begin{aligned} 5x+2y+z&=30 \\ \tfrac{1}{2}x+\tfrac{4}{6}y-\tfrac{1}{10}z&=4 \\ 2x+5y+10z&=129 \end{aligned}\right\}$

18. $\left.\begin{aligned} \tfrac{1}{2}x+\tfrac{1}{3}y&=12-\tfrac{1}{6}z \\ \tfrac{1}{2}y+\tfrac{1}{3}z-\tfrac{1}{6}x&=8 \\ \tfrac{1}{2}x+\tfrac{1}{3}z&=10 \end{aligned}\right\}$

[C U Entr Paper, 1868]

19. $\left.\begin{aligned} \frac{1}{x}+\frac{5}{y}-\frac{4}{z}&=\frac{1}{12} \\ \frac{3}{x}-\frac{4}{y}+\frac{5}{z}&=\frac{19}{24} \\ -\frac{4}{x}+\frac{5}{y}+\frac{6}{z}&=\frac{1}{2} \end{aligned}\right\}$

20. $\left.\begin{aligned} \frac{3}{x}-\frac{4}{5y}+\frac{1}{z}&=7\tfrac{3}{5} \\ \frac{1}{3x}+\frac{1}{2y}+\frac{2}{z}&=10\tfrac{1}{6} \\ \frac{4}{5x}-\frac{1}{2y}+\frac{4}{z}&=16\tfrac{1}{10} \end{aligned}\right\}$

21. $\left.\begin{aligned} 5x+3y&=65 \\ 2y-z&=11 \\ 3x+4z&=57 \end{aligned}\right\}$

22. $\left.\begin{aligned} \frac{2}{x}+\frac{1}{y}&=\frac{3}{2} \\ \frac{3}{z}-\frac{2}{y}&=2 \\ \frac{1}{x}+\frac{1}{z}&=\frac{4}{3} \end{aligned}\right\}$

23. $\left.\begin{aligned} ay+bx&=c \\ cx+az&=b \\ bz+cy&=a \end{aligned}\right\}$

24. $\left.\begin{aligned} 3x+4y-11&=0 \\ 5y-6z&=-8 \\ 7z-8x-13&=0 \end{aligned}\right\}$

[C U Entr Paper, 1877]

25. $\left.\begin{aligned} 3y+x-2&=0 \\ 3z-4y&=x+15 \\ 2x+7z&=7 \end{aligned}\right\}$ [C U Entrance Paper, 1883]

183. Miscellaneous Examples.

Example 1. Solve $\frac{a}{x}+\frac{b}{y}=1,\ \frac{b}{y}+\frac{c}{z}=1,\ \frac{c}{z}+\frac{a}{x}=1.$

Adding together the given equations, we have

$$2\left(\frac{a}{x}+\frac{b}{y}+\frac{c}{z}\right)=3,$$

$$\text{or,}\quad \frac{a}{x}+\frac{b}{y}+\frac{c}{z}=\frac{3}{2}. \quad \ldots \quad (\alpha)$$

Subtracting the 2nd equation from (α), we have

$$\frac{a}{x}=\frac{1}{2}; \qquad \therefore \quad x=2a$$

Similarly we have $y=2b$, and $z=2c$

Example 2. Solve

$$\text{(i)}\ \frac{xy}{x+y}=1, \quad \text{(ii)}\ \frac{xz}{x+z}=2, \quad \text{(iii)}\ \frac{yz}{y+z}=3$$

From (i), we have $\frac{x+y}{xy}=1$, or, $\frac{1}{y}+\frac{1}{x}=1$ ... (4)

" (ii) " " $\frac{x+z}{xz}=\frac{1}{2}$, or, $\frac{1}{z}+\frac{1}{x}=\frac{1}{2}$ ... (5)

" (iii) " " $\frac{y+z}{yz}=\frac{1}{3}$, or, $\frac{1}{z}+\frac{1}{y}=\frac{1}{3}$ ... (6)

From (4), (5) and (6), by addition, we have

$$2\left(\frac{1}{x}+\frac{1}{y}+\frac{1}{z}\right)=1+\frac{1}{2}+\frac{1}{3}=\frac{11}{6};$$

$$\frac{1}{x}+\frac{1}{y}+\frac{1}{z}=\frac{11}{12}. \quad \ldots \quad (7)$$

Subtracting (6) from (7),

$$\frac{1}{x}=\frac{11}{12}-\frac{1}{3}=\frac{7}{12}; \qquad \therefore \quad x=\tfrac{12}{7}.$$

Subtracting (5) from (7),

$$\frac{1}{y}=\frac{11}{12}-\frac{1}{2}=\frac{5}{12}; \qquad \therefore \quad y=\tfrac{12}{5}$$

Subtracting (4) from (7),

$$\frac{1}{z}=\frac{11}{12}-1=-\frac{1}{12}; \qquad \therefore \quad z=-12.$$

Example 3. Solve $xyz = a(yz - zx - xy)$
$$= b(zx - xy - yz) = c(xy - yz - zx)$$

Since $xyz = a(yz - zx - xy)$, we have

$$\frac{1}{a} = \frac{1}{x} - \frac{1}{y} - \frac{1}{z} \quad (1)$$ [Dividing both sides by $a \times xyz$]

Similarly, we have $\frac{1}{b} = \frac{1}{y} - \frac{1}{z} - \frac{1}{x}$ .. (2)

and $\frac{1}{c} = \frac{1}{z} - \frac{1}{x} - \frac{1}{y}$. . . (3)

Adding together (2) and (3), we have

$$-\frac{2}{x} = \frac{1}{b} + \frac{1}{c} = \frac{b+c}{bc}; \quad \therefore \quad x = \frac{-2bc}{b+c}.$$

Similarly $-\frac{2}{y} = \frac{1}{c} + \frac{1}{a} = \frac{a+c}{ac}; \quad \therefore \quad y = \frac{-2ca}{c+a},$

and $-\frac{2}{z} = \frac{1}{a} + \frac{1}{b} = \frac{a+b}{ab}; \quad \therefore \quad z = \frac{-2ab}{a+b}.$

Example 4. Solve
$$\left.\begin{aligned} x+y+z &= 0 \\ (b+c)x+(c+a)y+(a+b)z &= 0 \\ bcx+cay+abz &= 1 \end{aligned}\right\}$$

Since $\left.\begin{aligned} (b+c)x+(c+a)y+(a+b)z=0 \\ x+y+z=0 \end{aligned}\right\}$ and

Therefore, by cross multiplication,

$$\frac{x}{(c+a)-(a+b)} = \frac{y}{(a+b)-(b+c)} = \frac{z}{(b+c)-(c+a)},$$

or, $$\frac{x}{c-b} = \frac{y}{a-c} = \frac{z}{b-a}.$$

Supposing each of these fractions $= k$, we have

$$x = k(c-b),\ y = k(a-c),\ z = k(b-a).$$

Substituting these values of x, y, z in the third equation, we have $k\{bc(c-b) + ca(a-c) + ab(b-a)\} = 1$

But $bc(c-b) + ca(a-c) + ab(b-a)$
$$= bc(c-b) + a^2(c-b) - a(c^2 - b^2)$$
$$= (c-b)\{bc + a^2 - a(c+b)\}$$
$$= (c-b)(a-c)(a-b)$$

Thus, $k(c-b)(a-c)(a-b)=1,$

$$\therefore \quad k=\frac{1}{(c-b)(a-c)(a-b)}.$$

Hence,
$$x=k(c-b)=\frac{1}{(a-c)(a-b)};$$
$$y=k(a-c)=\frac{1}{(c-b)(a-b)};$$
$$z=k(b-a)=\frac{1}{(c-b)(c-a)}.$$

EXERCISE 98.

Solve the following equations.

1. $\frac{x}{a}+\frac{y}{b}=1, \quad \frac{x}{a}+\frac{z}{c}=1, \quad \frac{y}{b}+\frac{z}{c}=1.$

2. $\frac{1}{x}+\frac{1}{y}=a, \quad \frac{1}{x}+\frac{1}{z}=b, \quad \frac{1}{y}+\frac{1}{z}=c$

3. $\frac{yz}{y+z}=a, \quad \frac{zx}{z+x}=b, \quad \frac{xy}{x+y}=c$

4. $\left.\begin{aligned} axy&=c(bx+ay)\\ bxy&=c(ax-by)\end{aligned}\right\}$

5. $3xy=4(x+y), \quad 2xz=3(x+z), \quad 5yz=12(y+z)$

6. $y+z=4, \quad z+x=6, \quad x+y=8$

7. $y+z-x=6, \quad z+x-y=10, \quad x+y-z=14$

8. $\left.\begin{aligned} x-4y+z&=-10\\ y-4z+x&=-15\\ z-4x+y&=-35\end{aligned}\right\}$

9. $\left.\begin{aligned} y+z-7x+16&=0\\ z+x-7y+24&=0\\ x+y-7z+40&=0\end{aligned}\right\}$

10. $\left.\begin{aligned} a^2x+b^2y&=2ab(a+b)\\ b(2a+b)x+a(a+2b)y&=a^3+a^2b+ab^2+b^3\end{aligned}\right\}$

11. $\left.\begin{aligned} x+y+z&=A\\ ax+by+cz&=0\\ a^2x+b^2y+c^2z&=0\end{aligned}\right\}$

12. $\left.\begin{aligned} x+y+z&=0\\ (a+b)x+(a+c)y+(b+c)z&=0\\ abx+acy+bcz&=1\end{aligned}\right\}$

13. $\left.\begin{aligned} x+y+z&=0\\ \frac{x}{a}+\frac{y}{b}+\frac{z}{c}&=0\\ \frac{x}{a^2}+\frac{y}{b^2}+\frac{z}{c^2}&=1\end{aligned}\right\}$

14. $\left.\begin{aligned} x-ay+a^2z&=a^3\\ x-by+b^2z&=b^3\\ x-cy+c^2z&=c^3\end{aligned}\right\}$

15. $\left.\begin{array}{ll} ax+by+cz & =0 \\ (b+c)x+(c+a)y+(a+b)z & =0 \\ a^2x+b^2y+c^2z=a^2(b-c)+b^2(c-a)+c^2(a-b) & \end{array}\right\}$

16. Find the condition that the three equations,
$a_1x+b_1y+c_1=0, \quad a_2x+b_2y+c_2=0, \quad a_3x+b_3y+c_3=0,$
may be consistent

17. Find the value of a so that the four equations,
$2x-3y+5z=18, \quad 3x-y+4z=20, \quad 4x+2y-z=5,$
$(a+1)x+(a+2)y+(a+3)z=76$, may be consistent

18. $\left.\begin{array}{l} 3w-2y=2 \\ 5x-7z=11 \\ 2x+3y=39 \\ 4y+3z=41 \end{array}\right\}$

19. $\left.\begin{array}{ll} 9x-2z+w & =41 \\ 7y-5z-t & =12 \\ 4y-3x+2w & =5 \\ 3y-4w+3t & =7 \\ 7z-5w & =11 \end{array}\right\}$

20. $\left.\begin{array}{ll} x+y+z & =ab+bc+ca \\ \dfrac{x}{ab}+\dfrac{y}{bc}+\dfrac{z}{ca} & =3 \\ (c-b)x+(a-b)y+(c-a)z=2abc-ab^2-b^2c+ac^2-a^2c & \end{array}\right\}$

II. Problems producing simple equations with more than one unknown quantity.

148. In this section we shall consider a few problems of a harder type than those treated of in Chapter XVIII

The following examples will serve as illustrations

Example 1. A cask P contains 12 gallons of wine and 18 gallons of water, and another cask Q contains 9 gallons of wine and 3 gallons of water How many gallons must be drawn from each cask so as to produce by their mixture 7 gallons of wine and 7 gallons of water?

Out of 30 gallons of the mixture of wine and water in P, there are 12 gallons of wine; hence $\frac{12}{30}$ or $\frac{2}{5}$ths of the mixture consists of wine, and $\frac{3}{5}$ths of water

Hence, for every gallon drawn from P, there are taken out $\frac{2}{5}$ths of a gallon of wine and $\frac{3}{5}$ths of a gallon of water

Similarly, for every gallon drawn from Q, there are taken out $\frac{3}{4}$ths of a gallon of wine and $\frac{1}{4}$th of a gallon of water

Let x= the number of gallons to be drawn from P,
and y= " " " " " " " Q

Then, since x gallons from P contain $\frac{2}{5}x$ gallons of wine and $\frac{3}{5}x$ gallons of water, and y gallons from Q contain $\frac{3}{4}y$ gallons of wine and $\frac{1}{4}y$ gallons of water, in the new mixture there are $(\frac{2}{5}x+\frac{3}{4}y)$ gallons of wine and $(\frac{3}{5}x+\frac{1}{4}y)$ gallons of water.

Hence, by the conditions of the problem,

$$\left.\begin{aligned} &\tfrac{2}{5}x+\tfrac{3}{4}y=7 && \quad (1)\\ \text{and}\quad &\tfrac{3}{5}x+\tfrac{1}{4}y=7. && \quad (2)\end{aligned}\right\}$$

Multiplying (2) by 3, and subtracting (1) from the resulting equation, we have

$$\tfrac{7}{5}x=14; \qquad x=10$$

Hence, from (2), $y=4(7-\frac{3}{5}\times 10)=4$

Thus 10 gallons must be drawn from P, and 4 gallons from Q

Example 2. The fore-wheel of a carriage makes 6 revolutions more than the hind-wheel in going 120 yards, if the circumference of the fore-wheel be increased by one-fourth of its present size, and the circumference of the hind-wheel by one-fifth of its present size, the *six* will be changed to *four* Required the circumference of each wheel

Let x yards be the circumference of the four-wheel,
and „ y „ „ „ , „ , hind-wheel

Then the numbers of revolutions made by the wheels in going 120 yards are respectively $\dfrac{120}{x}$ and $\dfrac{120}{y}$.

When the circumference of the fore-wheel is increased by one-fourth, and that of the hind-wheel by one-fifth, the circumferences respectively become

$$\left(x+\frac{x}{4}\right) \text{ and } \left(y+\frac{y}{5}\right) \text{ yards, or, } \frac{5x}{4} \text{ and } \frac{6y}{5} \text{ yards.}$$

Therefore, the numbers of revolutions made by the wheels respectively will be

$$120\div\frac{5x}{4} \text{ and } 120\div\frac{6y}{5}, \text{ or, } \frac{96}{x} \text{ and } \frac{100}{y}.$$

Hence, from the conditions of the problem,

$$\left.\begin{aligned} &\frac{120}{x}=\frac{120}{y}+6 && \quad (1)\\ \text{and}\quad &\frac{96}{x}=\frac{100}{y}+4 && \quad (2)\end{aligned}\right\}$$

Multiplying (1) by 5 and (2) by 6, we have

$$\frac{600}{x}=\frac{600}{y}+30,$$

and $$\frac{576}{x}=\frac{600}{y}+24,$$

$\therefore$ by subtraction, $\frac{24}{x}=6$, $\therefore x=4$

Hence, from (1), $\frac{120}{y}=\frac{120}{4}-6=24$; $\therefore y=5$

Thus the circumferences of the wheels are respectively 4 and 5 yards

Example 3. A pound of tea and three pounds of sugar cost six shillings; but if sugar were to rise 50 per cent, and tea 10 per cent, they would cost seven shillings Find the price of tea and sugar

Let x shillings be the price of a pound of tea, and y shillings, the price of a pound of sugar; then we must have

$$x+3y=6 \quad \ldots \quad \ldots \quad \ldots (1)$$

When the price of tea *rises* 10 *per cent*, the price of a pound of tea becomes $\left(x+\frac{x}{10}\right)$, or, $\frac{11}{10}x$ shillings; and the price of sugar *rising* 50 *per cent*, the price of a pound of sugar becomes $\left(y+\frac{y}{2}\right)$, or, $\frac{3y}{2}$ shillings.

Hence, $$\frac{11}{10}x+3\cdot\frac{3y}{2}=7. \quad \ldots (2)$$

From (2), $\frac{11}{5}x+9y=14$,

and from (1), $3x+9y=18$;

$\therefore (3-\frac{11}{5})x=4$;

or, $\frac{4x}{5}=4$; $\therefore x=5$

Hence from (1). $y=\frac{6-5}{3}=\frac{1}{3}$.

Thus the price of a pound of tea$=5s$ and that of a pound of sugar$=\frac{1}{3}s=4d$

Example 4. A certain sum of money is to be divided among a certain number of men, if there were 3 men less

each man would have £150 more, but if there were 6 men more, each man would have £120 less Find the sum of money and the number of men

Let x = the sum of money in pounds,

and y = the number of men.

Therefore, each man gets £$\frac{x}{y}$; if there were 3 men less, each would get £$\frac{x}{y-3}$; and if there were 6 men more, each would get £ $\frac{x}{y+6}$.

Hence, from the conditions of the problem,

$$\frac{x}{y-3}=\frac{x}{y}+150 \qquad \text{(1)}$$

and $$\frac{x}{y+6}=\frac{x}{y}-120 \qquad \text{(2)}$$

From (1), $$150=x\left(\frac{1}{y-3}-\frac{1}{y}\right)$$

$$=\frac{3x}{y^2-3y}; \qquad \therefore \quad x=50(y^2-3y)$$

From (2), $$120=x\left(\frac{1}{y}-\frac{1}{y+6}\right)$$

$$=\frac{6x}{y^2+6y}; \qquad \therefore \quad x=20(y^2+6y)$$

Hence, $50(y^2-3y)=20(y^2+6y)$,

or, $30y^2=(150+120)y=270y$, $\therefore$ $y=9$

$\therefore$ $x=20(81+54)=20\times 135=2700.$

Thus there are 9 men and a sum of £2700

Example 5. A man has to travel a certain distance When he has travelled 40 miles, he increases his speed 2 miles per hour If he had travelled with his increased speed during the whole of his journey, he would have arrived 40 minutes earlier, but if he had continued at his original speed, he would have arrived 20 minutes later How far had he to travel?

Let x = the number of miles the man had to travel; and suppose his original speed was y miles an hour.

Hence, the time actually taken to complete the journey $=\left(\frac{40}{y}+\frac{x-40}{y+2}\right)$ hours $=\frac{80+xy}{y(y+2)}$ hours.

The time he would have taken if he had travelled at the increased speed during the whole of his journey $=\frac{x}{y+2}$ hours, and the time he would have taken if he had travelled all the way at his original speed $=\frac{x}{y}$ hours

Hence, from the conditions of the problem,

$$\frac{x}{y+2}=\frac{80+xy}{y(y+2)}-\frac{2}{3} \quad \ldots \quad (1)$$

and

$$\frac{x}{y}=\frac{80+xy}{y(y+2)}+\frac{1}{3}. \quad \ldots \quad (2)$$

Subtracting (1) from (2),

$$x\left(\frac{1}{y}-\frac{1}{y+2}\right)=1,$$

$$\text{or,} \quad 2x=y(y+2). \quad \ldots \quad (3)$$

Also from (2),

$$3x(y+2)=3(80+xy)+y(y+2),$$

$$\text{or,} \quad 6x-240=y(y+2). \quad \ldots \quad (4)$$

Hence, from (3) and (4),

$$6x-240=2x,$$

$$\text{or,} \quad 4x=240; \quad \therefore \quad x=60$$

Thus the man had to travel 60 miles

Example 6. If there were no accidents, it would take half as long to travel the distance from A to B by rail road as by coach, but three hours being allowed for accidental stoppages by the former, the coach will travel the distance all but fifteen miles in the same time; if the distance were two-thirds as great as it is, and the same time allowed for railway stoppages, the coach would take exactly the same time. Required the distance

Let x miles be the distance from A to B

Suppose the coach travels at the rate of y miles an hour, then evidently, the rate of the train is $2y$ miles an hour

The time in which the train can travel the distance *plus* 3 hours = the time in which the coach travels only $(x-15)$ miles.

Hence, $\dfrac{x}{2y}+3=\dfrac{x-15}{y}$, ... (1)

and $\dfrac{\frac{2}{3}x}{2y}+3=\dfrac{\frac{2}{3}x}{y}$, or, $\dfrac{x}{3y}+3=\dfrac{2x}{3y}$. ... (2)

From (2), $\dfrac{x}{3y}=3$, or, $x=9y$ (3)

From (1), $x+6y=2x-30$, or, $6y=x-30$ .. (4)

Hence, from (3) and (4), $6y=9y-30$,

whence $y=10$;

and $\therefore$ $x=9\times10=90$

Then the required distance $=90$ miles.

Example 7. A boat goes up stream 30 miles and down stream 44 miles in 10 hours, it also goes up stream 40 miles and down stream 55 miles in 13 hours; find the rate of the stream and of the boat. [C U. Entr Paper, 1880]

Suppose the boat will travel x miles per hour if there were no current, and that the current flows at the rate of y miles per hour.

Then it is clear that *with the current* the boat travels $x+y$ miles per hour, and *against the current*, $x-y$ miles per hour

Hence, the time taken to travel 30 miles up stream $=\dfrac{30}{x-y}$ hours, and the time taken to travel 44 miles down stream $=\dfrac{44}{x+y}$ hours, and $\therefore$ by the 1st condition of the problem, we must have

$$\frac{30}{x-y}+\frac{44}{x+y}=10. \quad ... \quad (1)$$

Similarly, by the 2nd condition, we have

$$\frac{40}{x-y}+\frac{55}{x+y}=13. \quad ... \quad (2)$$

Multiplying (1) by 4, and (2) by 3, we have

$$\frac{120}{x-y}+\frac{176}{x+y}=40$$

and

$$\frac{120}{x-y}+\frac{165}{x+y}=39$$

Therefore, by subtraction,

$$\frac{11}{x+y}=1; \quad \therefore \quad x+y=11.$$

Hence, from (1), $$\frac{30}{x-y}=10-4=6;$$

$$\therefore \quad x-y=5$$

Thus we have
$$\left.\begin{aligned} x+y&=11 \\ \text{and} \quad x-y&=5 \end{aligned}\right\}$$

Hence, by addition, $2x=16$, $\therefore$ $x=8$

and by subtraction, $2y=6$, $\therefore$ $y=3$

Thus the rates of the stream and the boat are respectively 3 miles and 8 miles per hour

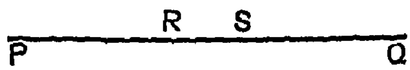
Example 8. *A* challenged *B* to ride a bicycle race of 1040 yards He first gave *B*, 120 yards' start, but lost by 5 seconds, he then gave *B*, 5 seconds' start, and won by 120 feet How long does each take to ride the distance?

[C U Entr Paper, 1881.]

Let the times which *A* and *B* take to ride the distance be x seconds and y seconds respectively

Then, the times they take to travel one yard are respectively $\frac{x}{1040}$ and $\frac{y}{1040}$ seconds.

Let PQ represent the given distance, and let PR, SQ on it respectively represent 120 yards and 120 feet (or, 40 yards).



In the first race *B* is at *R*, and *A* at *P* when they start, but *B* reaches *Q*, 5 seconds earlier than *A*; therefore, the time taken by *B* to travel $RQ=(x-5)$ seconds

Hence, $$x-5=(1040-120)\times\frac{y}{1040}$$

$$=(1-\tfrac{3}{26})y=\tfrac{23}{26}y \qquad . \qquad . \qquad (1)$$

In the second race *B* starts from *P*, 5 seconds earlier than *A*, but arrives at *S* when *A* arrives at *Q*; therefore, the time taken by *B* to travel $PS=(x+5)$ seconds

Hence, $x+5=(1040-40)\times\frac{y}{1040}$

$=(1-\frac{1}{26})y=\frac{25}{26}y$ ... ... (2)

Subtracting (1) from (2), we have

$\frac{2}{26}y=10;$ $\therefore$ $y=130$

Hence, from (1), $x=5+\frac{23}{26}\times 130$

$=5+115=120.$

Thus the times required by A and B to ride the distance are respectively 2 minutes, and 2 minutes 10 seconds.

Example 9. If the sum of the digits of a number is divisible by 9, so is the number [B C S 1923]

If the number consists of one digit it must evidently be 9. Thus, the problem is true for a number of one digit

If the number consists of two digits, let x and y be the digits in the unit's and ten's place respectively

$\therefore$ The number $=10y+x$.

Now, $\frac{10y+x}{9}=y+\frac{y+x}{9}$.

Hence, the number is divisible by 9 if $x+y$ is divisible by 9, *i e*, if the sum of the digits is divisible by 9

Proceeding similarly, the proof follows for a number with more digits

EXERCISE 99.

1. There is a certain number consisting of 3 digits which is equal to 25 times the sum of the digits, and if 198 be added to the number, the digits will be reversed, also the sum of the extreme digits exceeds the middle digit by unity; find the number

2. A shop-keeper, on account of bad book-keeping knows neither the weight nor the prime cost of a certain article which he purchased He only recollects that if he had sold the whole at 30*s* per lb, he would have gained £5 by it, and if he had sold it at 22*s* per lb, he would have lost £15 by it What was the weight and prime cost of the article?

3. Two persons, A and B, played cards After a certain number of games, A had won half as much as he had at first and found that if he had 15 shillings more, he would have had

just three times as much as B But B afterwards won 10 shillings back, and he had then twice as much as A. What had each at first?

4. A and B can do a piece of work together in 12 days, which B working for 15 days and C for 30 would together complete, in 10 days they would finish it, working all three together, in what time could they separately do it?

5. A has twice as many pennies as shillings; B, who has 8*d* more than A, has twice as many shillings as pennies, together they have one more penny than they have shillings How much has each?

6. Two persons, A and B could finish a work in m days; they worked together n days when A was called off, and B finished it in p days In what time could each do it?

7. A, B, C compare their fortunes, A says to B, 'give me Rs 700 of your money, and I shall have twice as much as you retain', B says to C, 'give me Rs 1400, and I shall have thrice as much as you have remaining', C says to A, 'give me Rs 420, and then I shall have five times as much as you retain' How much has each?

8. A man walks 35 miles partly at the rate of 4 miles an hour, and partly at 5, if he had walked at 5 miles an hour when he walked at 4, and *vice versa*, he would have covered two miles more in the same time Find the time he was walking

9. A train travelled a certain distance at a uniform rate. Had the speed been 6 miles an hour more, the journey would have occupied 4 hours less, and had the speed been 6 miles an hour less, the journey would have occupied 6 hours more. Find the distance

10. Two vessels contain mixtures of wine and water; in one there is three times as much wine as water, in the other five times as much water as wine Find how much must be drawn off from each to fill a third vessel which holds seven gallons, in order that its contents may be half wine and half water

11. A number consists of 3 digits whose sum is 10 The middle digit is equal to the sum of the other two, and the number will be increased by 99 if its digits be reversed Find the number

12. A man has one pound's worth of silver in half crowns, shillings and six-pences; and he has in all 20 coins. If he

changed the six-pences for pennies, and the shilling or six-pences, he would have 73 coins How many coins of each kind has he?

13. A sum of money is divided equally among a certain number of persons; if there had been four more, each would have received a shilling less than he did, if there had been five fewer, each would have received two shillings more than he did, find the number of persons and what each received.

14. There is a cistern, into which water is admitted by three cocks, two of which are exactly of the same dimensions. When they are all open, five-twelfths of the cistern is filled in four hours, and if one of the equal cocks is stopped, seven-ninths of the cistern is filled in ten hours and forty minutes. In how many hours would each cock fill the cistern?

15. A person exchanged 12 bushels of wheat for 8 bushels of barley, and £2 16*s*, offering at the same time to sell a certain quantity of wheat for an equal quantity of barley, and £3 15*s* in money, or for £10 in money Required the prices of the wheat and barley per bushel

16. A wine-merchant has two sorts of wine, one sort worth 2 shillings a quart, and the other worth 3*s* 4*d* a quart; from these he wants to make a mixture of 100 quarts worth 2*s* 4*d* a quart How many quarts must he take from each sort?

17. The rent of a farm is paid in certain fixed number of quarters of wheat and barley; when wheat is at 55*s*. and barley at 33*s* per quarter, the portions of rent by wheat and barley are equal to one another, but when wheat is at 65*s* and barley at 41*s* per quarter, the rent is increased by £7. What is the corn-rent?

18. A train 60 yards long passed another train 72 yards long which was travelling in the same direction on a parallel line of rails, in 12 seconds Had the slower train been travelling half as fast again, it would have been passed in 24 seconds Find the rates at which the trains were travelling

19. A farmer with 28 bushels of barley at 2*s* 4*d* a bushel, would mix rye at 3*s* per bushel, and wheat at 4*s* per bushel, so that the whole mixture may consist of 100 bushels, and be worth 3*s* 4*d* per bushel How many bushels of rye, and how many of wheat must he mix with the barley?

20. A person has £27 6*s* in guineas and crown-pieces; out of which he pays a debt of £14 17*s*, and finds that he

has exactly as many guineas left as he has paid away crowns, and as many crowns as he has paid away guineas How many of each had he at first and how many of each had he left ?

21. A waterman finds that he can row with the tide from A to B, a distance of 18 miles, in an hour and a half, and that to return from B to A against the same tide, though he rows back along the shore where the stream is only three-fifths as strong as in the middle, takes him just two hours and a quarter Find the rate at which the tide runs in the middle where it is strongest

22. A and B run a mile First A gives B a start of 44 yards, and beats him by 51 seconds, at the second heat A gives B a start of 1 minute 15 seconds, and is beaten by 88 yards Find the times in which A and B can run a mile separately.

23. A and B run a race round a two-mile course In the first heat B reaches the winning post 2 minutes before A In the second heat A increases his speed by 2 miles an hour, and B diminishes his by the same quantity, and A then arrives at the winning post 2 minutes before B. Find at what rate each ran in the first heat

24. A railway train running from London to Cambridge meets on the way with an accident, which causes it to diminish its speed to $\frac{1}{n}$th of what it was before, and it is in consequence a hours late If the accident had happened b miles nearer Cambridge, the train would have been c hours late Find the rate of the train before the accident occurred

25. A railway train after travelling for one hour, meets with an accident, which delays it one hour, after which it proceeds at three-fifths of its former rate, and arrives at the terminus three hours behind time, had the accident occurred 50 miles further on, the train would have arrived 1 hour 20 minutes sooner Required the length of the journey

26. If the difference between the sums of the odd and even digits of a number is zero or divisible by 11, the number is divisible by 11. [B C S 1923]

27. If the sum of the digits of a number is divisible by 3, so is the number

CHAPTER XXVIII

GRAPHS AND THEIR APPLICATIONS

185. We have explained in Chapters VII and XIX how algebraic expressions can be represented graphically by points and lines

We shall now give some illustrations of the way in which graphs may be used to solve algebraic equations and problems Graphical solutions are generally in the nature of approximation, but in many cases they are obtained more easily than the corresponding exact solutions by algebraic processes explained previously

186. Graphical Solution of Equations.

Example. Solve graphically

$$\left.\begin{array}{l} 2x-7y+12=0 \\ 3x+2y=32 \end{array}\right\}$$

Let us draw the graphs of the two equations

We find that

$\left.\begin{array}{l} x=-6 \\ y=0 \end{array}\right\}$, $\left.\begin{array}{l} x=1 \\ y=2 \end{array}\right\}$ are points on the graph of the 1st equation ;

whilst

$\left.\begin{array}{l} x=0 \\ y=16 \end{array}\right\}$, $\left.\begin{array}{l} x=6 \\ y=7 \end{array}\right\}$ are points on the graph of the 2nd equation.

Hence, taking the length of a side of a small square as the unit of length, the two graphs are as shewn on the next page.

Let P be the point where the two graphs intersect, P being common to the graphs, its co-ordinates will satisfy both the given equations.

Now the co-ordinates of P are found to be 8 and 4.

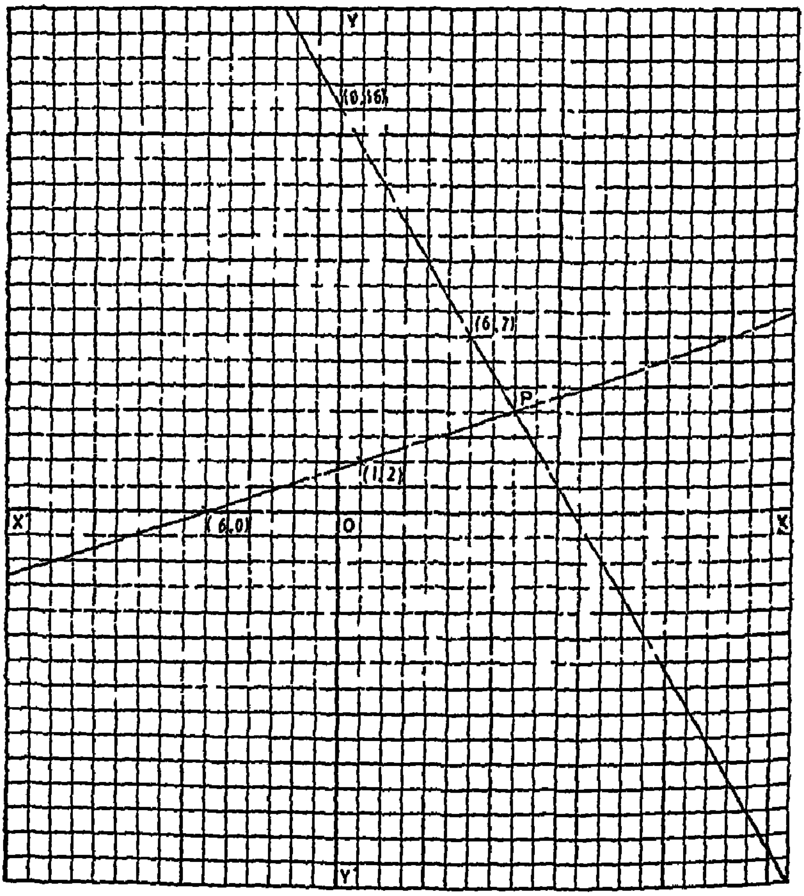
Hence, $\left.\begin{array}{l} x=8 \\ y=4 \end{array}\right\}$ is the required solution.

Verification: Substituting $x=8$ and $y=4$ in the given equations, we have

$$2x-7y+12=2\times8-7\times4+12=0,$$

and $$3x+2y-32=3\times8+2\times4-32=0.$$

$\therefore$ Both the equations are satisfied when $x=8$ and $y=4$.



Example 2. Solve graphically $\frac{2x+12}{7}=\frac{32-3x}{2}$.

All that we have to do is to draw the graphs of the expressions $\frac{2x+12}{7}$ and $\frac{32-3x}{2}$, and take the *abscissa* of the point common to the two graphs.

The graph of the function $\frac{2x+12}{7}$ is the same as the graph of $y=\frac{2x+12}{7}$, *i e*, $2x-7y+12=0$, and graph of the function $\frac{32-3x}{2}$ is the same as that of $y=\frac{32-3x}{2}$, *i e*, $3x+2y=32$

Drawing the graphs of $2x-7y+12=0$ and $3x+2y=32$ (see example 1 above), we find that the abscissa of the common point, P, of the graphs $=8$

$\therefore$ $x=8$ is the required solution.

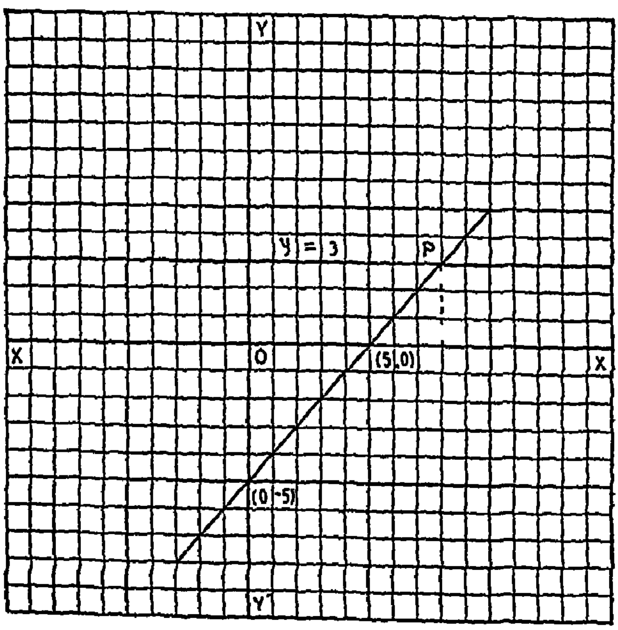
Example 3. Solve graphically $x-5=3$

Let us draw the graphs of the expressions $x-5$ and 3 The abscissa of the point common to the two graphs is the required solution

Now, the graph of the expression $x-5$ is the same as the graph of $y=x-5$; and we find that

$$\left.\begin{matrix} x=\ \ 0 & \text{and} & x=5 \\ y=-5 & & y=0 \end{matrix}\right\} \text{ are points on this graph}$$

Also, the graph of the expression 3 is the same as the graph of $y=3$, which is a straight line parallel to x-axis at a distance of 3 units from the origin.

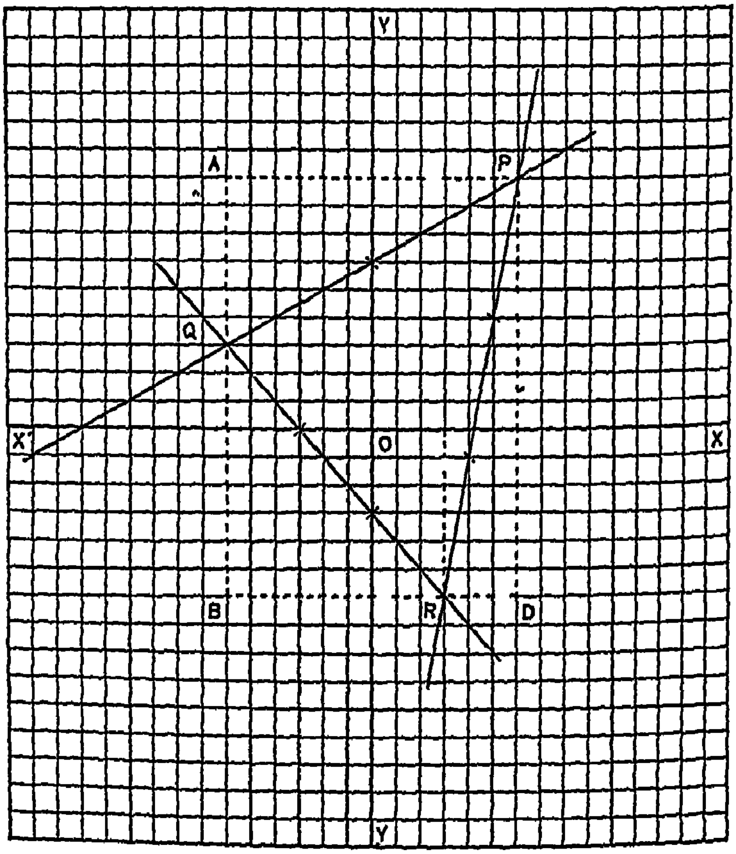


Hence, taking the length of a side of a small square as the unit of length the two graphs are as shown in the figure.

Let P be the point where the two graphs intersect. We find that the abscissa of $P=8$

$\therefore$ $x=8$ is the required solution.

Example 4. Find the co-ordinates of the vertices of the triangles whose sides are given by the equations $x-2y+12=0$, $x+y+3=0$ and $5x-y-21=0$, and calculate its area



We find that $\left.\begin{array}{l}x=0\\y=6\end{array}\right\}$ and $\left.\begin{array}{l}x=-12\\y=0\end{array}\right\}$ are points on the graph of $x-2y+12=0$;

whilst $\left.\begin{array}{l}x=0\\y=-3\end{array}\right\}$ and $\left.\begin{array}{l}x=-3\\y=0\end{array}\right\}$ are points on the graph of $x+y+3=0$,

and $\left.\begin{array}{l}x=4\\y=-1\end{array}\right\}$ and $\left.\begin{array}{l}x=5\\y=4\end{array}\right\}$ are points on the graph of $5x-y-21=0$

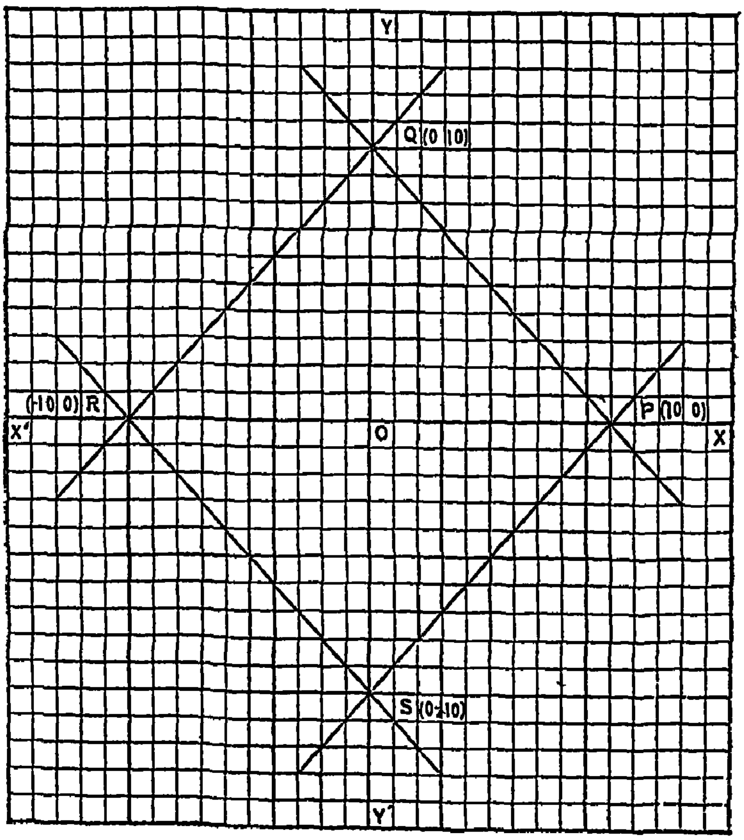
Hence, taking the length of a side of a small square as the unit of length, the straight lines PQ, QR and RP represent the graphs of the 1st, 2nd and 3rd equations respectively

We find from the diagram that the co-ordinates of the vertex P are $\left.\begin{array}{l}x=6\\y=9\end{array}\right\}$; of Q, $\left.\begin{array}{l}x=-6\\y=\ \ 3\end{array}\right\}$ and of R, $\left.\begin{array}{l}x=\ \ 3\\y=-6\end{array}\right\}$

Drawing lines parallel to the axes (as shown in the diagram by dotted lines), we have

$$\triangle PQR = \text{the rect } \triangle ABDP - \triangle QAP - \triangle QBR - \triangle RDP$$
$$= AB \times BD - \frac{AP \times AQ}{2} - \frac{QB \times BR}{2} - \frac{RD \times DP}{2}$$
$$= 15 \times 12 - \frac{12 \times 6}{2} - \frac{9 \times 9}{2} - \frac{3 \times 15}{2}$$
$$= 180 - 36 - \tfrac{81}{2} - \tfrac{45}{2} = 81 \text{ units of area}$$

xample 5. Find graphically the co-ordinates of the vertices of the quadrilateral whose sides are $x+y-10=0$, $x-y+10=0$, $x+y+10=0$ and $x-y-10=0$ Prove that the quadrilateral is a square and find its area



We find that

$\left.\begin{array}{l} x=10 \\ y=0 \end{array}\right\}$ and $\left.\begin{array}{l} x=0 \\ y=10 \end{array}\right\}$ are points on the graph of $x+y-10=0$,

$\left.\begin{array}{l} x=0 \\ y=10 \end{array}\right\}$ and $\left.\begin{array}{l} x=-10 \\ y=0 \end{array}\right\}$ are points on the graph of $x-y+10=0$;

$\left.\begin{array}{l} x=0 \\ y=-10 \end{array}\right\}$ and $\left.\begin{array}{l} x=-10 \\ y=0 \end{array}\right\}$ are points on the graph of $x+y+10=0$;

whilst

$\left.\begin{array}{l} x=0 \\ y=-10 \end{array}\right\}$ and $\left.\begin{array}{l} x=10 \\ y=0 \end{array}\right\}$ are points on the graph of $x-y-10=0$

Hence, taking the side of the small square as the unit of length, the four graphs are represented by the straight lines PQ, QR, RS and SP [See the diagram, page 397]

We notice that the co-ordinates of the vertices P, Q, R, and S are

$\left.\begin{array}{l} x=10 \\ y=0 \end{array}\right\}$, $\left.\begin{array}{l} x=0 \\ y=10 \end{array}\right\}$, $\left.\begin{array}{l} x=-10 \\ y=0 \end{array}\right\}$ and $\left.\begin{array}{l} x=0 \\ y=-10 \end{array}\right\}$ respectively.

It is obvious from the diagram that $OP=OQ=OR=OS$, each being 10 units long and the diagonal PR is perp to QS

Hence, it follows from geometry that the quadrilateral $PQRS$ is a square

The area required $=\Delta PQR+\Delta PSR$

$$=\frac{PR\times OQ}{2}+\frac{PR\times OS}{2}$$

$$=\frac{20\times 10}{2}+\frac{20\times 10}{2}=200 \text{ units of area}$$

EXERCISE 100.

Solve the following equations graphically

1. $x+y=9$, $3x-2y=7$.

2. $4x+3y=13$, $3x+2y=11$

3. $\frac{x}{4}+\frac{y}{3}=4$, $4x-5y=2$.

4. $y-x=2$, $3x-2y=5$

5. $5x-3y=11$, $2y-3x+4=0$

6. $\frac{x-2}{2}=\frac{-5x+4}{5}$.

7. $\frac{2x+7}{3}=\frac{3x-7}{2}$.

8. $\frac{4x-3}{5}=\frac{6x}{7}-1$

9. $x-12=-3.$ **10.** $5x-13=7$

11. Find the vertices of the triangle whose sides are given by $-x+3y=18$, $x+7y=22$ and $y+3x=26$ and calculate its area

12. Show that the straight lines $4x-y=16$, $3x-2y=7$ and $x+y=9$ meet at a point Find its co-ordinates

13. Find the vertices and the areas of the quadrilaterals whose sides are given by (i) $x+y=3$, $\frac{x}{3}-\frac{y}{3}=1$, $\frac{x+y}{3}=-1$, and $x-y+3=0$, (ii) $x=1$, $y=5$, $x=12$ and $y=10$, (iii) $x=0$ $y=0$, $\frac{x}{3}+\frac{y}{5}=1$, $\frac{x}{8}+\frac{y}{12}=1$

14. Find the vertices and the areas of the triangles whose sides are given by (i) $x=0$, $y=0$, $\frac{x}{5}+\frac{y}{6}=1$; (ii) $x-2=0$, $y-1=0$, $x+y=6$, (iii) $x-2y+8=0$, $x+y+2=0$, $5x-y-14=0$.

In each of the following examples, show by solving the equations that they are satisfied by the same values of x and y.

Find these values and verify graphically:

15. $x+y=2$, $x=1$, $y=1$

16. $7x+5y=24$, $x+y=2$, $2x+y=9$.

17. $2x-y=7$, $y-x=2$, $11x=9y$

187. Application of Graphs to Problems.

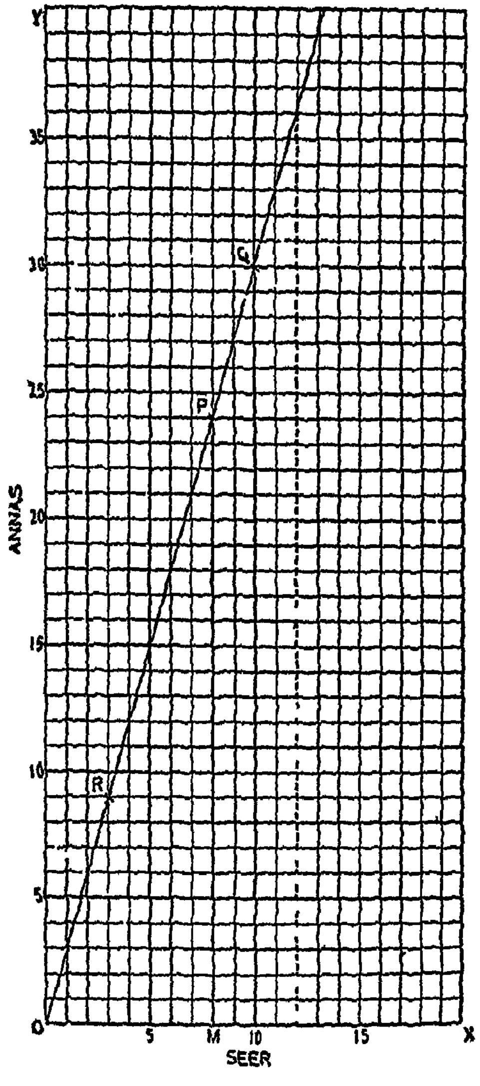
Example 1. Given that the price of a seer of rice is three annas, show that a graph in the form of a straight line can be drawn such that if any point be taken on it, the abscissa of the point will represent the quantity of rice of which the price is represented by the ordinate

Determine from the graph (i) the price of 12 seers and (ii) the number of seers that can be had for 27 annas

In the figure on the next page let the length of a side of a small square measured along OX represent one seer, and let an equal length measured along OY represent one anna Then the meaning of the figures along OX and OY is clear.

Since, the price of a seer is 3 annas, the price of 8 seers must be 24 annas Clearly therefore P is a point such that

its abscissa OM represents a quantity of rice of which the price is represented by the ordinate PM



Join OP and produce it Then this is the straight line every point on which will satisfy a condition similar to that satisfied by P

Q is the point (10, 30), consequently its abscissa represents a quantity of rice of which the price is represented by its ordinate R is the point (3, 9), its abscissa therefore represents a quantity of rice of which the price is represented by its ordinate Similarly this is true of every point on the line OP.

Hence OP is the required straight line

The graph enables us to determine readily the price of any given number of seers of rice For instance, if the asbcissa be taken to be 12, the ordinate is immediately found to be 36, thus we know that the price of 12 seers of rice is 36 annas Similarly, for any other abscissa the corresponding ordinate can be immediately found

The graph also enables us to determine quickly the number of seers of rice that can be had for any given price For instance, if the ordinate is taken to be 27, the corresponding abscissa is immediately found to be 9, which shows that we can have 9 seers of rice for 27 annas

Note *The line OP is called the graph of the price of rice, or more simply the* ***price-graph*** *of rice*

Example 2. A person, named B, starting from a given place, travels at the rate of 5 miles an hour Show that a graph in the form of a straight line can be drawn such that if any point be taken on it, the abscissa of the point will represent the number of miles that B travels in the time represented by the ordinate

Determine from the graph (i) the distance travelled in 3 hours 24 minutes and (ii) the time to travel 13 miles

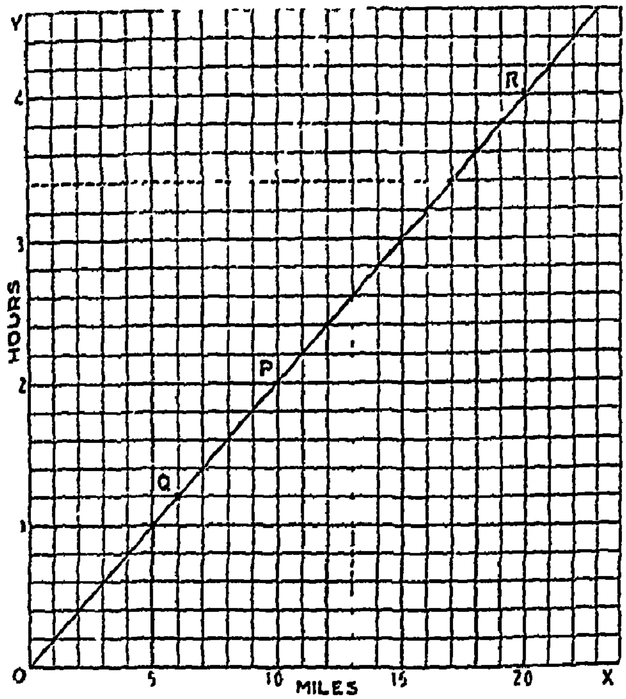
In the figure on the next page let the length of a side of a small square measured along OX represent one mile, and let an equal length measured along OY represent 12 minutes Then the meaning of the figures along OX and OY is clear

Since B travels 5 miles in one hour, he travels 10 miles in 2 hours Clearly therefore P is a point such that its abscissa represents the number of miles that the person travels in the time represented by its ordinate

Join OP and produce it Then this is the straight line every point on which will satisfy a condition similar to that satisfied by P

Let Q be any point on the line Its abscissa represents 6 miles and ordinate represents 1 hour 12 minutes, but we *know* that the person travels 6 miles in 1 hour 12 minutes

Hence Q satisfies the condition mentioned above



Let R be some other point on the line Its abscissa represents 20 miles and ordinate represents 4 hours, but we *know* that the person travels 20 miles in 4 hours

Hence, R also satisfies the proposed condition

Similarly for any other point on the line

Hence, OP is the required straight line

The graph enables us to determine readily the time in which B travels any given number of miles For instance, if the abscissa be taken which represents 13 miles, the corresponding ordinate is immediately found to be that which represents 2 hours 36 minutes; thus it is known that the time taken by the person to travel 13 miles in 2 hours 36 minutes

The graph also enables us to determine readily the number of miles that the person travels in any given time For instance, if the ordinate be taken which represents 3 hours 24 minutes the corresponding abscissa is immediately found to be that which represents 17 miles; thus it is known that in 3 hours and 24 minutes the person travels 17 miles

Note *The line OP is called the graph of B's motion, or the motion-graph of B.*

Example 3. If one inch be equal in length to 2 5 centimetres, show that a straight line can be drawn such that the abscissa of any point on the line will represent the number of inches that are equivalent to the number of centimetres represented by the ordinate

Determine from the graph (i) the number of centimetres in 10 inches and (ii) the number of inches in 15 centimetres

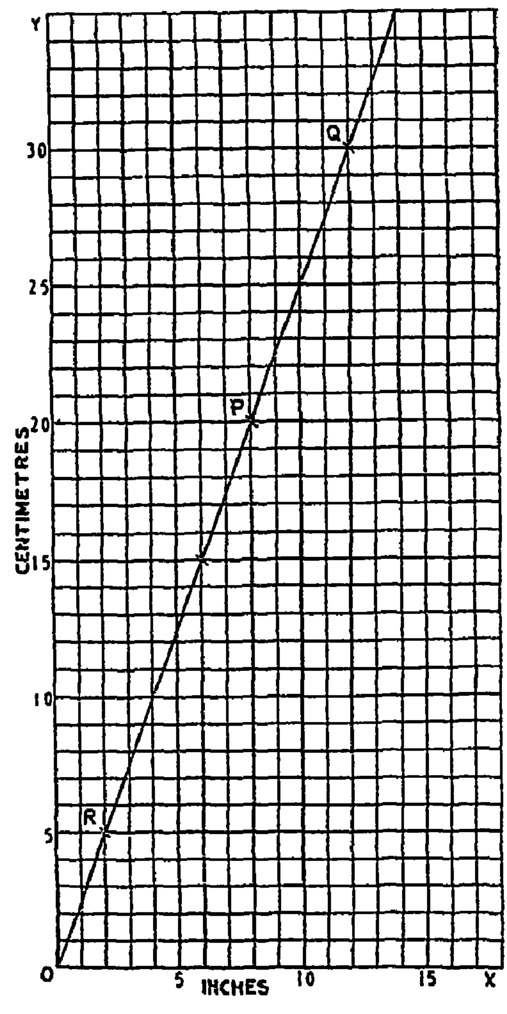
In the figure below let the length of a side of a small square measured along OX represent one inch, and let an equal length measured along OY represent one centimetre Then the meaning of the figures along OX and OY is clear

Since 1 inch=2 5 centimetres, we have 8 inches =20 centimetres Clearly therefore P is a point such that its abscissa represents the number of inches that are equivalent to the number of centimetres represented by its ordinate

Join OP and produce it Then this is the straight line every point on which will satisfy a condition similar to that satisfied by P

Let Q be any point on the line Its abscissa represents 12 inches whilst its ordinate represents 30 centimetres, but we *know* that these two are equivalent Hence Q satisfies the condition above mentioned

Let R be some other point on the line Its abscissa represents 2 inches, whilst its ordinate represents 5 centimetres, but we *know* that these two are equivalent Hence R also satisfies the proposed condition



Similarly for any other point on the line Hence OP is the required straight line

The graph enables us to determine readily the number of centimetres that are equivalent to any given number of inches For instance, if the abscissa be taken which represents 10 inches, the corresponding ordinate is immediately found to be that which represents 25 centimetres. thus it is known that 10 inches are equivalent to 25 centimetres.

The graph also enables us to determine readily the number of inches that are equivalent to any given number of centimetres for instance if the ordinate be taken which represents 15 centimetres the corresponding abscissa is immediately found to be that which represents 6 inches. thus it is known that 15 centimetres are equivalent to 6 inches

Note *The line OP is called the graph for converting inches into centimetres and vice versa, or more briefly the* ***convertion graph for inches and centimetres.***

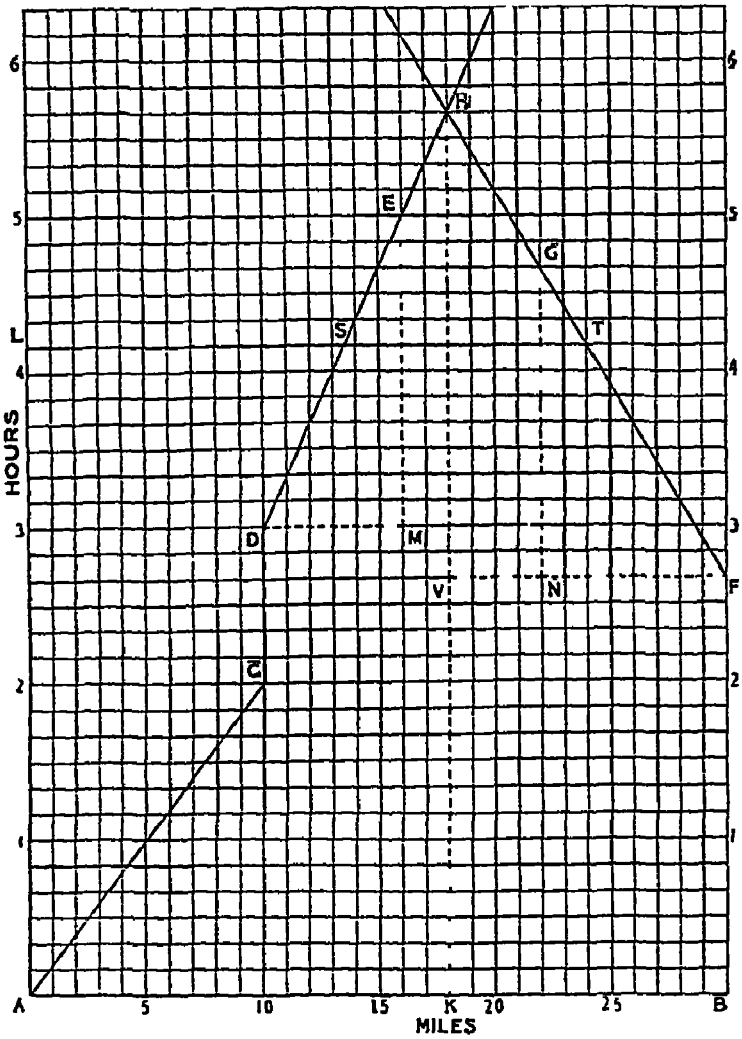
Example 4. A and B are two stations 30 miles apart. P starts from A and travels towards B at the rate of 5 miles an hour, at the end of 2 hours he takes rest for one hour, and then resumes his journey at the rate of 3 miles an hour. Q leaves B, 2 hours 40 minutes after P leaves A, and travels towards A, without stoppage, at the rate of 4 miles an hour. When and where will the two travellers meet ?

Let the length of a side of a small square measured horizontally represent one mile, and let an equal length measured vertically represent 10 minutes Then the meaning of the figures along the lines in the diagram on the next page is clear

(1) P starts from A and travelling at the rate of 5 miles an hour, completes 10 miles in 2 hours Hence if the point C be taken such that its co-ordinates respectively represent 10 miles and 2 hours, AC is the graph of Ps motion for the first two hours

The graph for the 3rd hour must be such that the abscissa of any point on it may represent 10 miles, because P is supposed to be at rest throughout this hour Hence CD drawn vertically to represent one hour as in the diagram, will be the graph of P's rest

After the 3rd hour P travels at the rate of 3 miles an hour Hence if DM be taken to represent 6 miles and ME



to represent 2 hours the straight line DE is the graph of P's motion after the 3rd hour

Thus the broken line $ACDE$ is the complete graph of P's motion

(ii) Q starts from B, 2 hours 40 minutes after P leaves A Hence if BF be measured vertically to represent 2 hours 40 minutes BF may be regarded as the graph of Q's rest at B

When Q leaves B, he moves towards A at the rate of 4 miles an hour Hence if FN be taken to represent 8 miles

and NG to represent 2 hours, the straight line FG will be the graph of Q's motion

(iii) Let the two graphs intersect at H, and draw HK perpendicular to AB Produce FN to meet HK at V

Now it is clear that at the end of time HK, P will have gone a distance AK towards B and Q will have gone a distance BK (i e, FV) towards A Hence they will meet at this instant Thus the required time of meeting = that represented by HK=5 hours 40 minutes after the commencement of P's motion

Also, the distance of the place of meeting from A = that represented by AK = 18 miles

Note 1 *As HV represents 3 hours it is clear that P and Q meet at the end of 3 hours after Q starts from B*

Note 2 *The horizontal line through L meets the graphs at the points S and T AL represents 4 hours 10 minutes and ST represents $10\frac{1}{2}$ miles, it is clear that at the end of 4 hours 10 minutes from the commencement of P's motion, P and Q are at a distance of $10\frac{1}{2}$ miles from each other*

EXERCISE 101.

1. If milk sells for 4 annas per seer construct the price-graph of milk, giving the price of any quantity of milk up to 5 seers From the graph read off the price of 3 seers and 5 chattacks of milk, and also the quantity of milk that can be had for 10 annas and 9 pies

2. If *Fazli* mangoes be worth one rupee two annas a dozen, construct a price-graph for mangoes, giving the price of any number up to 30 Read off from the graph the price of 17 mangoes and also the number of mangoes that can be had for Re 1 12 as 6p

3. If a man walks at the rate of 4 miles an hour construct a graph of his motion Read off from the graph the time in which he travels 13 miles, and also the number of miles he travels in $4\frac{3}{4}$ hours

4. If one cubit be equal to 1 5 feet, construct a conversion-graph for cubits and feet Read off from the graph the number of feet that are equivalent to $5\frac{3}{4}$ cubits, and also the number of cubits that are equivalent to $6\frac{3}{4}$ feet

5. A starts from a place and walks in a given direction at the rate of 3 miles an hour; B starts from the same place one hour later and moves in the same direction at

the rate of 5 miles an hour Draw the motion-graphs of A and B, and find when and where B overtakes A

6. A and B are two stations 20 miles apart P starts from A and travels towards B at the rate of 3 miles an hour, whilst Q starting from B travels towards A at the rate of 2 miles an hour Construct the motion-graphs of P and Q, and find when and where they meet

7. Fifty articles of the same kind cost Rs 3 2 as Construct a graph from which you can read off the cost of any number of articles upto 50 Hence find the cost of 19 articles, and the number of articles that you would get for Rs 2 7 as

8. Given that 1 kilogramme=22 lbs, construct a graph which will enable you to read off the number of kilogrammes that are equivalent to any given number of lbs upto 15 lbs Read off the number of kilogrammes in 11 lbs

9. A man travels for 3 hours at the rate of 2 miles an hour, at the end of which he takes rest for an hour and a half, and then starts to walk at the rate of two miles and a half per hour Construct the graph of his motion

10. A man starts from a place B to walk towards C at the rate of 4 miles an hour After 3 hours he changes his mind and walks back towards B at the rate of 3 miles an hour At the end of 2 hours again he suddenly changes his mind and begins to run towards C at the rate of 7 miles an hour Draw a graph of his motion

11. A, B and C are three stations in order on the same road, the distance between A and B being 6 miles Q starts from B at noon to walk towards C at the rate of 3 miles an hour, and at 1-30 P M P starts from A to run towards C at the rate of $6\frac{1}{2}$ miles an hour Draw graphs of their motion, and find when and where P will overtake Q

12. A man spends Rs 620 in 40 days Draw a graph to give his expenditure in any number of days Determine from the graph the amount spent in 28 days

13. At what time between 3 and 4 o'clock are the two hands of a watch together?

14. An income-tax of 5 pies per rupee is in force Draw a graph to show the tax on all incomes from Rs 3000 to Rs 5000 and determine the income corresponding to a tax of Rs 85 and the tax corresponding to an income of Rs 4350

15. The following table shows the timings of two trains, one an express from Calcutta to Ranaghat, and the other a

local from Naihati to Calcutta Find by graphical methods when and where the trains meet, assuming that all runs are at constant speeds and that the local train waits one minute at each station between Naihati and Calcutta

Distance from Calcutta				
46	Ranaghat			17-56
24	Naihati	dep	16-24	
22	Kakinara	"	16-29	
19	Shamnagar	"	16-36	
17	Ichhapur	"	16-42	
15	Palta	"	16-45	
14	Barrackpur	"	16-49	
13	Tittagarh	"	16-53	
12	Khardah	"	16-57	
10	Sodepur	"	17- 2	
9	Agarpara	"	17- 6	
8	Belghurria	"	17-11	
5	Dum-Dum	"	17-19	
	Calcutta	"	17-31	16-42

[B C S 1922]

CHAPTER XXIX

ELEMENTARY LAWS OF INDICES

188. Definition. The product of m factors each equal to a is represented by a^m [Art 16]

Thus the meaning of a^m is clear when m is a *positive integer*

189. The Index Law and the truths necessarily following from it.

To prove that $a^m \times a^n = a^{m+n}$, where m and n are any two positive integers

Since $a^m = a\,a\,a$ to m factors

and $a^n = a\,a\,a\,a$ to n factors

$$
\begin{aligned}
a^m \times a^n &= (a\,a\,a \quad \text{to } m \text{ factors}) \\
&\quad \times (a\,a\,a\,a \quad \text{to } n \text{ factors}) \\
&= a\,a\,a\,a\,a\,a\,a \quad \text{to } (m+n) \text{ factors} \\
&= a^{m+n}
\end{aligned}
$$

This result is called the **Index Law.**

Cor. 1. $a^m \times a^n \times a^p = a^{m+n+p}$, when m n and p are positive integers

For, $a^m \times a^n = a^{m+n}$, $\qquad a^m \times a^n \times a^p = a^{m+n} \times a^p = a^{(m+n)+p} = a^{m+n+p}$

Hence, $a^m \times a^n \times a^p \times a^q \times \quad = a^{m+n+p+q+}$

Thus, *the product of any number of powers of a given quantity is that power of the quantity whose index is equal to the sum of the indices of the factors*

Cor. 2. $(a^m)^n = a^{mn}$, when m and n are any two positive integers

For, $(a^m)^n = a^m \times a^m \times a^m \times \quad$ to n factors

$$= a^{m+m+m+ \quad \text{to } n \text{ terms}} \qquad \text{[by Cor 1]}$$

and $\qquad = a^{mn}$

Cor. 3. $a^m \div a^n = a^{m-n}$, when m and n are positive integers and m is greater than n

For $a^{m-n} \times a^n = a^{(m-n)+n}$ [because $m-n$ is a positive integer]

$$= a^m,$$

$$a^m \div a^n = a^{m-n}$$

190. Assuming the formula $a^m \times a^n = a^{m+n}$ to be true for *all* values of m and n, to find meanings for quantities with fractional or negative indices.

(1) To find the meaning of $a^{\frac{p}{q}}$, when p and q are any two positive integers

Since $a^m \times a^n = a^{m+n}$ for *all* values of m and n, putting $\frac{p}{q}$ for each of them, we have

$$a^{\frac{p}{q}} \times a^{\frac{p}{q}} = a^{\frac{p}{q}+\frac{p}{q}} = a^{\frac{2p}{q}}$$

Similarly $a^{\frac{p}{q}} \times a^{\frac{p}{q}} \times a^{\frac{p}{q}} = a^{\frac{2p}{q}} \times a^{\frac{p}{q}} = a^{\frac{3p}{q}}$, and so on

Hence $a^{\frac{p}{q}} \times a^{\frac{p}{q}} \times a^{\frac{p}{q}} \times$ to q factors

$$= a^{\frac{qp}{q}} = a^p$$

Thus, $a^{\frac{p}{q}}$ is equal to the q^{th} root of a^p and is, therefore, equivalent to $\sqrt[q]{a^p}$

Cor. Hence $a^{\frac{1}{2}} = \sqrt{a}$, $a^{\frac{1}{3}} = \sqrt[3]{a}$, $a^{\frac{1}{4}} = \sqrt[4]{a}$, and so on

Generally, $a^{\frac{1}{n}} = \sqrt[n]{a}$

Note. *From the Index Law it is also easy to see that* $a^{\frac{1}{q}} \times a^{\frac{1}{q}} \times a^{\frac{1}{q}} \times$ *to p factors* $= a^{\frac{p}{q}}$. *Thus* $a^{\frac{p}{q}}$ *may as well be regarded as the p^{th} power of* $a^{\frac{1}{q}}$, *i e, equivalent to* $(\sqrt[q]{a})^p$ *Thus* $a^{\frac{p}{q}}$ *may be interpreted either as the q^{th} root of the p^{th} power of a, or as the p^{th} power of the q^{th} root of a*

(ii) To find the meaning of a^0

Since $a^m \times a^n = a^{m+n}$ is true for *all* values of m and n putting $m=0$ we have

$$a^0 \times a^n = a^{0+n} = a^n,$$

$$\therefore a^0 = a^n \div a^n = 1$$

Thus, *any quantity raised to the power zero is equivalent* to 1

(iii) To find the meaning of a^{-n} where n is any positive integer

Since $a^m \times a^n = a^{m+n}$ is true for *all* values of m and n, putting $m = -n$ we have

$$a^{-n} \times a^n = a^{-n+n} = a^0 = 1$$

$$\therefore a^{-n} = \frac{1}{a^n}, \text{ and } a^n = \frac{1}{a^{-n}}$$

Cor. Hence $a^m \div a^n = a^{m-n}$ for *all* values of m and n

For $a^m \div a^n = \frac{a^m}{a^n} = a^m \times a^{-n} = a^{m-n}$

Example 1. Find the value of $8^{\frac{5}{3}}$

$$8^{\frac{5}{3}}=\left(\sqrt[3]{8}\right)^5=2^5=32$$

Example 2. Find the value of $4^{-\frac{5}{2}}$

$$4^{-\frac{5}{2}}=\frac{1}{4^{\frac{5}{2}}}=\frac{1}{(\sqrt{4})^5}=\frac{1}{2^5}=\frac{1}{32}$$

Example 3. Multiply together

$$\sqrt{a^5} \quad a^{\frac{3}{4}} \quad \sqrt[4]{a^{-5}} \text{ and } \frac{1}{a^{-3}}$$

$$\text{The required product}=a^{\frac{5}{2}}\times a^{\frac{3}{4}}\times a^{-\frac{5}{4}}\times a^3$$
$$=a^{\frac{5}{2}+\frac{3}{4}-\frac{5}{4}+3}$$
$$=a^{\frac{5}{2}-\frac{1}{2}+3}=a^{2+3}=a^5$$

EXERCISE 102.

Express the following avoiding fractional or negative indices

1. $a^{\frac{5}{7}}$ **2.** $x^{-\frac{3}{2}}$ **3.** $\dfrac{3}{x^{-\frac{4}{5}}}$.

4. $x^{-\frac{2}{5}}\times 3a^{-\frac{1}{2}}$ **5.** $8m^{-2}\times m^{-\frac{2}{3}}$ **6.** $x^{-\frac{4}{5}}-3a^{-\frac{5}{4}}$

7. $x^{-\frac{2}{3}}-2x^{-\frac{1}{2}}$ **8.** $\sqrt[5]{x^2}-\sqrt[5]{x^{-a}}$

9. $\sqrt[2m]{a^{-5}}\times\sqrt[m]{a^8}$ **10.** $\sqrt[4a]{x^6}-\sqrt[2a]{x^{-5}}$

Express the following avoiding radical signs and negative indices

11. $\left(\sqrt[4]{x}\right)^7$ **12.** $\left(\sqrt[4]{a}\right)^{-6}$ **13.** $\dfrac{1}{\sqrt[3]{x^{-2}}}$.

14. $\dfrac{1}{(\sqrt[5]{a})^{-2}}$ **15.** $\sqrt[3]{x^4}-(\sqrt[6]{x})^{-1}$ **16.** $\sqrt[4]{a^{-3}}-(\sqrt[8]{a})^{-12}$.

Find the value of

17. $4^{-\frac{3}{2}}$ **18.** $8^{\frac{2}{3}}$ **19.** $9^{\frac{3}{2}}$

20. $16^{\frac{5}{4}}$ **21.** $81^{-\frac{3}{4}}$ **22.** $\dfrac{1}{6^{-2}}$

23. $(125)^{-\frac{2}{3}}$ **24.** $(\frac{1}{27})^{-\frac{4}{3}}$ **25.** $(\frac{1}{216})^{-\frac{2}{3}}$

26. Simplify $\dfrac{x^{m+2n}x^{3m-8n}}{x^{5m-6n}}$. [C U Entrance Paper 1874]

191. To prove that $(a^m)^n = a^{mn}$ is true for *all* values of m and n.

(i) Let n be a *positive integer* Then, whatever may be the value of m, we have

$$(a^m)^n = a^m \times a^m \times a^m \times \quad \text{to } n \text{ factors}$$
$$= a^{\overbrace{m+m+m+}^{\text{to } n \text{ terms}}}$$
$$= a^{mn}$$

(ii) Let n be a *positive* fraction equal to $\frac{p}{q}$, where p and q are positive integers Then we have

$$\left(a^m\right)^n = \left(a^m\right)^{\frac{p}{q}} = \sqrt[q]{\left(a^m\right)^p} \quad \text{[Art 190, (i)]}$$
$$= \sqrt[q]{a^{mp}} \quad \text{[by (i)]}$$
$$= a^{\frac{mp}{q}} \quad \text{[Art 190, (i)]}$$
$$= a^{mn}$$

(iii) Let n be *any negative* quantity, equal to $-p$, where p is *positive* Then we have

$$(a^m)^n = (a^m)^{-p} = \frac{1}{(a^m)^p} \quad \text{[Art 190, (iii)]}$$
$$= \frac{1}{a^{mp}} \quad \text{[by (i) and (ii)]}$$
$$= a^{-mp} \quad \text{[Art 190 (iii)]}$$
$$= a^{m(-p)} = a^{mn}$$

Thus the proposition is established

192. To prove that $a^n b^n = (ab)^n$ for *all* values of n.

(i) Let n be a *positive integer* Then we have

$$a^n b^n = (a\ a\ a \quad \text{to } n \text{ factors})$$
$$\times (b\ b\ b \quad \text{to } n \text{ factors})$$
$$= (ab\ ab\ ab \quad \text{to } n \text{ factors})$$
$$= (ab)^n$$

(ii) Let n be a *positive fraction* equal to $\frac{p}{q}$, where p and q are positive integers. Then putting x for $a^n b^n$, we have

$$x = a^{\frac{p}{q}} b^{\frac{p}{q}}, \qquad x^q = \left(a^{\frac{p}{q}} b^{\frac{p}{q}}\right)^q$$

$$= \left(a^{\frac{p}{q}}\right)^q \times \left(b^{\frac{p}{q}}\right)^q \qquad \text{[by (i)]}$$

$$= a^p \times b^p \qquad \text{[Art. 189]}$$

$$= (ab)^p, \qquad \text{[by (i)]}$$

$$\therefore x = (ab)^{\frac{p}{q}}, \text{ i.e., } a^n b^n = (ab)^n.$$

(iii) Let n be *any negative* quantity, equal to $-p$, where p is positive. Then we have

$$a^n b^n = a^{-p} b^{-p}$$

$$= \frac{1}{a^p b^p} \qquad \text{[Art. 188, (iii)]}$$

$$= \frac{1}{(ab)^p} \qquad \text{[by (i) and (ii)]}$$

$$= (ab)^{-p} \qquad \text{[Art. 188, (iii)]}$$

$$= (ab)^n.$$

Thus the proposition is established.

Cor. 1. $\frac{a^n}{b^n} = a^n b^{-n} = a^n \left(b^{-1}\right)^n = \left(ab^{-1}\right)^n = \left(\frac{a}{b}\right)^n.$

Cor. 2. $a^n b^n c^n = (ab)^n c^n = (abc)^n$,

generally, $a^n b^n c^n d^n \ldots = (abcd \ldots)^n$.

193. Applications of the results proved in the last two articles.

Example 1. Simplify $\left(a^8 b^{\frac{5}{3}}\right)^{-\frac{3}{4}}$.

$$\left(a^8 b^{\frac{5}{3}}\right)^{-\frac{3}{4}} = \left(a^8\right)^{-\frac{3}{4}} \times \left(b^{\frac{5}{3}}\right)^{-\frac{3}{4}}$$

$$= a^{8 \times \left(-\frac{3}{4}\right)} \times b^{\frac{5}{3} \times \left(-\frac{3}{4}\right)}$$

$$= a^{-6} b^{-\frac{5}{4}}.$$

Example 2. Simplify $\sqrt{a^{-2}b} \times \sqrt[3]{ab^{-3}}$.

$$\sqrt{a^{-2}b} = \left(a^{-2}b\right)^{\frac{1}{2}} = \left(a^{-2}\right)^{\frac{1}{2}} \times b^{\frac{1}{2}} = a^{-1} b^{\frac{1}{2}}$$

and $\sqrt[3]{ab^{-3}} = \left(ab^{-3}\right)^{\frac{1}{3}} = a^{\frac{1}{3}} \times \left(b^{-3}\right)^{\frac{1}{3}} = a^{\frac{1}{3}} b^{-1}$.

Hence, the given expression

$$=a^{-1}b^{\frac{1}{2}}\times a^{\frac{1}{3}}b^{-1}$$

$$=a^{-1+\frac{1}{3}}\times b^{\frac{1}{2}-1}=a^{-\frac{2}{3}}b^{-\frac{1}{2}}$$

Example 3. Simplify $\sqrt{a^3b^{-\frac{2}{3}}c^{-\frac{7}{6}}}-\sqrt[3]{a^4b^{-1}c^{\frac{5}{4}}}$

$$\sqrt{a^3b^{-\frac{2}{3}}c^{-\frac{7}{6}}}=\left(a^3b^{-\frac{2}{3}}c^{-\frac{7}{6}}\right)^{\frac{1}{2}}$$

$$=\left(a^3\right)^{\frac{1}{2}}\left(b^{-\frac{2}{3}}\right)^{\frac{1}{2}}\left(c^{-\frac{7}{6}}\right)^{\frac{1}{2}}$$

$$=a^{\frac{3}{2}}b^{-\frac{1}{3}}c^{-\frac{7}{12}},$$

and $$\sqrt[3]{a^4b^{-1}c^{\frac{5}{4}}}=\left(a^4b^{-1}c^{\frac{5}{4}}\right)^{\frac{1}{3}}$$

$$=\left(a^4\right)^{\frac{1}{3}}\left(b^{-1}\right)^{\frac{1}{3}}\left(c^{\frac{5}{4}}\right)^{\frac{1}{3}}$$

$$=a^{\frac{4}{3}}b^{-\frac{1}{3}}c^{\frac{5}{12}}$$

Hence, the given expression

$$=a^{\frac{3}{2}}b^{-\frac{1}{3}}c^{-\frac{7}{12}}-a^{\frac{4}{3}}b^{-\frac{1}{3}}c^{\frac{5}{12}}$$

$$=a^{\frac{3}{2}}b^{-\frac{1}{3}}c^{-\frac{7}{12}}\times a^{-\frac{4}{3}}b^{\frac{1}{3}}c^{-\frac{5}{12}}$$

$$=a^{\frac{3}{2}-\frac{4}{3}}b^{-\frac{1}{3}+\frac{1}{3}}c^{-\frac{7}{12}-\frac{5}{12}}$$

$$=a^{\frac{1}{6}}b^0c^{-1}=a^{\frac{1}{6}}c^{-1}$$

EXERCISE 103.

Simplify

1. $\left(a^{-\frac{3}{4}}\right)^8$ **2.** $\left(a^{-\frac{2}{3}}b^{\frac{5}{6}}\right)^{\frac{1}{4}}$ **3.** $\left(a^{-\frac{1}{2}}b^{-1}\right)^{2}$

4. $\left(a^6b^{\frac{5}{4}}\right)^{-\frac{4}{3}}$ **5.** $\left(\sqrt[3]{a^4b^3}\right)^6$ **6.** $\left(\sqrt[6]{x^9y^{-8}}\right)^{3}$

7. $\sqrt[8]{x^2\sqrt[4]{x^{-3}}}$. **8.** $\sqrt{a^{-3}b^4}\times\sqrt[4]{a^2b^{-8}}$

9. $\sqrt[4]{x^{-2}\sqrt{y^5}}\times\sqrt{x\sqrt[4]{y^3}}$

10. $\left(8x^3-27a^{-3}\right)^{\frac{2}{3}}$ **11.** $\left(64x^3-27a^{-3}\right)^{-\frac{2}{3}}$

12. $\sqrt[3]{a^6b^{-2}c^{-4}}\times\sqrt[4]{a^{-6}b^4c^8}$

13. $\sqrt{a^{-\frac{2}{3}}b^4c^{-\frac{1}{3}}}-\sqrt[3]{a^2b^4c^{-1}}$

14. $\sqrt{ab^{-2}c^3}-\left(\sqrt[3]{a^3b^2c^{-3}}\right)^{-1}$ **15.** $\left(\dfrac{a^{-1}b^2}{a^2b^{-4}}\right)^7-\left(\dfrac{a^3b^{-5}}{a^{-2}b^3}\right)^5$

194. Miscellaneous Examples.

Example 1. Divide $a+b+c+3a^{\frac{1}{3}}b^{\frac{2}{3}}+3a^{\frac{2}{3}}b^{\frac{1}{3}}$ by $a^{\frac{1}{3}}+b^{\frac{1}{3}}+c^{\frac{1}{3}}$

Let us proceed by arranging the dividend and the divisor according to descending powers of a

$$
\begin{array}{l|l|l}
a^{\frac{1}{3}}+(b^{\frac{1}{3}}+c^{\frac{1}{3}}) & a+3a^{\frac{2}{3}}b^{\frac{1}{3}}+3a^{\frac{1}{3}}b^{\frac{2}{3}}+(b+c) & a^{\frac{2}{3}}+a^{\frac{1}{3}}(2b^{\frac{1}{3}}-c^{\frac{1}{3}}) \\
 & \underline{a+a^{\frac{2}{3}}(b^{\frac{1}{3}}+c^{\frac{1}{3}})} & \quad +(b^{\frac{2}{3}}-b^{\frac{1}{3}}c^{\frac{1}{3}}+c^{\frac{2}{3}}) \\
 & a^{\frac{2}{3}}(2b^{\frac{1}{3}}-c^{\frac{1}{3}})+3a^{\frac{1}{3}}b^{\frac{2}{3}}+(b+c) & \\
 & \underline{a^{\frac{2}{3}}(2b^{\frac{1}{3}}-c^{\frac{1}{3}})+a^{\frac{1}{3}}(2b^{\frac{2}{3}}+b^{\frac{1}{3}}c^{\frac{1}{3}}-c^{\frac{2}{3}})} & \\
 & a^{\frac{1}{3}}(b^{\frac{2}{3}}-b^{\frac{1}{3}}c^{\frac{1}{3}}+c^{\frac{2}{3}})+(b+c) & \\
 & \underline{a^{\frac{1}{3}}(b^{\frac{2}{3}}-b^{\frac{1}{3}}c^{\frac{1}{3}}+c^{\frac{2}{3}})+(b+c)} &
\end{array}
$$

Thus the reqd quotient $=a^{\frac{2}{3}}+2a^{\frac{1}{3}}b^{\frac{1}{3}}-a^{\frac{1}{3}}c^{\frac{1}{3}}+b^{\frac{2}{3}}-b^{\frac{1}{3}}c^{\frac{1}{3}}+c^{\frac{2}{3}}$

Note *In multiplication as well as in division the arrangement of the expressions concerned according to ascending or descending powers of some common letter should* ***never*** *be overlooked Such arrangements invariably give neatness to the required operations, if not always indispensable*

Example 2. Divide $x+y^{\frac{1}{2}}+z^{\frac{1}{3}}-3x^{\frac{1}{3}}y^{\frac{1}{6}}z^{\frac{1}{9}}$ by $x^{\frac{1}{3}}+y^{\frac{1}{6}}+z^{\frac{1}{9}}$

Putting a for $x^{\frac{1}{3}}$, b for $y^{\frac{1}{6}}$ and c for $z^{\frac{1}{9}}$, we have

$$
\begin{aligned}
x+y^{\frac{1}{2}}+z^{\frac{1}{3}}-3x^{\frac{1}{3}}y^{\frac{1}{6}}z^{\frac{1}{3}} &= a^3+b^3+c^3-3abc \\
&=(a+b+c)(a^2+b^2+c^2-ab-bc-ca) \\
&=(x^{\frac{1}{3}}+y^{\frac{1}{6}}+z^{\frac{1}{9}})\{(x^{\frac{1}{3}})^2+(y^{\frac{1}{6}})^2+(z^{\frac{1}{9}})^2-x^{\frac{1}{3}}y^{\frac{1}{6}}-y^{\frac{1}{6}}z^{\frac{1}{9}}-z^{\frac{1}{9}}x^{\frac{1}{3}}\} \\
&=(x^{\frac{1}{3}}+y^{\frac{1}{6}}+z^{\frac{1}{9}})(x^{\frac{2}{3}}+y^{\frac{1}{3}}+z^{\frac{2}{9}}-x^{\frac{1}{3}}y^{\frac{1}{6}}-y^{\frac{1}{6}}z^{\frac{1}{9}}-z^{\frac{1}{9}}x^{\frac{1}{3}})
\end{aligned}
$$

Hence, the required quotient

$$=x^{\frac{2}{3}}+y^{\frac{1}{3}}+z^{\frac{2}{9}}-x^{\frac{1}{3}}y^{\frac{1}{6}}-y^{\frac{1}{6}}z^{\frac{1}{9}}-z^{\frac{1}{9}}x^{\frac{1}{3}}$$

$$=x^{\frac{2}{3}}-x^{\frac{1}{3}}(y^{\frac{1}{6}}+z^{\frac{1}{9}})+(y^{\frac{1}{3}}-y^{\frac{1}{6}}z^{\frac{1}{9}}+z^{\frac{2}{9}})$$

Example 3. Divide

$$x^{2^n}+a^{2^{n-1}}x^{2^{n-1}}+a^{2^n} \text{ by } x^{2^{n-1}}-a^{2^{n-2}}x^{2^{n-2}}+a^{2^{n-1}}$$

Let $\quad m=x^{2^{n-2}}$ and $p=a^{2^{n-2}}$

Then $\quad m^2=\left(x^{2^{n-2}}\right)^2=x^{2\times 2^{n-2}}=x^{2^{n-1}},$

and $\quad m^4=\left(m^2\right)^2=\left(x^{2^{n-1}}\right)^2=x^{2\times 2^{n-1}}=x^{2^n}$

Similarly, $p^2=a^{2^{n-1}}$ and $p^4=a^{2^n}$

Hence, $$\frac{x^{2^n}+a^{2^{n-1}}x^{2^{n-1}}+a^{2^n}}{x^{2^{n-1}}-a^{2^{n-2}}x^{2^{n-2}}+a^{2^{n-1}}}$$

$$=\frac{m^4+m^2p^2+p^4}{m^2-mp+p^2}=\frac{(m^2+p^2)^2-m^2p^2}{m^2-mp+p^2}$$

$$=\frac{(m^2+p^2+mp)(m^2+p^2-mp)}{m^2-mp+p^2}$$

$$=m^2+mp+p^2$$

$$=x^{2^{n-1}}+x^{2^{n-2}}a^{2^{n-2}}+a^{2^{n-1}}$$

Example 4. Find the H C F of

$a^2+2b^2+(a+2b)\sqrt{ab}$ and $a^2-b^2+(a-b)\sqrt{ab}$

The 1st expression $=a^2+a\sqrt{ab}+2b\sqrt{ab}+2b^2$

$$=a^2+a^{\frac{2}{3}}b^{\frac{1}{2}}+2a^{\frac{1}{2}}b^{\frac{3}{2}}+2b^2$$

$$=a^{\frac{3}{2}}(a^{\frac{1}{2}}+b^{\frac{1}{2}})+2b^{\frac{3}{2}}(a^{\frac{1}{2}}+b^{\frac{1}{2}})$$

$$=(a^{\frac{1}{2}}+b^{\frac{1}{2}})(a^{\frac{3}{2}}+2b^{\frac{3}{2}})$$

The 2nd expression $=a^2+a\sqrt{ab}-b\sqrt{ab}-b^2$

$$=a^2+a^{\frac{3}{2}}b^{\frac{1}{2}}-a^{\frac{1}{2}}b^{\frac{3}{2}}-b^2$$

$$=a^{\frac{3}{2}}(a^{\frac{1}{2}}+b^{\frac{1}{2}})-b^{\frac{3}{2}}(a^{\frac{1}{2}}+b^{\frac{1}{2}})$$

$$=(a^{\frac{1}{2}}+b^{\frac{1}{2}})(a^{\frac{3}{2}}-b^{\frac{3}{2}})$$

Hence, since $a^{\frac{3}{2}}+2b^{\frac{3}{2}}$ and $a^{\frac{3}{2}}-b^{\frac{3}{2}}$ have no common factor, the H C F required

$$=a^{\frac{1}{2}}+b^{\frac{1}{2}}=\sqrt{a}+\sqrt{b}$$

Example 5. Simplify $\dfrac{x+(xy^2)^{\frac{1}{3}}-(x^2y)^{\frac{1}{3}}}{x+y}$.

The numerator $=x+x^{\frac{1}{3}}y^{\frac{2}{3}}-x^{\frac{2}{3}}y^{\frac{1}{3}}$

$$=x^{\frac{1}{3}}\left(x^{\frac{2}{3}}+y^{\frac{2}{3}}-x^{\frac{1}{3}}y^{\frac{1}{3}}\right),$$

and the denominator $=\left(x^{\frac{1}{3}}\right)^3+\left(y^{\frac{1}{3}}\right)^3$

$$=\left(x^{\frac{1}{3}}+y^{\frac{1}{3}}\right)\left\{\left(x^{\frac{1}{3}}\right)^2-\left(x^{\frac{1}{3}}\right)\left(y^{\frac{1}{3}}\right)+\left(y^{\frac{1}{3}}\right)^2\right\}$$

$$=\left(x^{\frac{1}{3}}+y^{\frac{1}{3}}\right)\left(x^{\frac{2}{3}}-x^{\frac{1}{3}}y^{\frac{1}{3}}+y^{\frac{2}{3}}\right)$$

Hence, the given expression $=\dfrac{x^{\frac{1}{3}}}{x^{\frac{1}{3}}+y^{\frac{1}{3}}}$

Example 6. Show that

$$\frac{1}{1+x^{m-n}+x^{m-p}}+\frac{1}{1+x^{n-m}+x^{n-p}}+\frac{1}{1+x^{p-m}+x^{p-n}}=1$$

The 1st term $=\dfrac{x^{-m}}{x^{-m}(1+x^{m-n}+x^{m-p})}$

$$=\frac{x^{-m}}{x^{-m}+x^{-n}+x^{-p}};$$

the 2nd term $=\dfrac{x^{-n}}{x^{-n}+(1+x^{n-m}+x^{n-p})}$

$$=\frac{x^{-n}}{x^{-n}+x^{-m}+x^{-p}};$$

and the 3rd term $=\dfrac{x^{-p}}{x^{-p}(1+x^{p-m}+x^{p-n})}$

$$=\frac{x^{-p}}{x^{-p}+x^{-m}+x^{-n}}.$$

Hence, the given expression

$$=\frac{x^{-m}}{x^{-m}+x^{-n}+x^{-p}}+\frac{x^{-n}}{x^{-n}+x^{-m}+x^{-p}}+\frac{x^{-p}}{x^{-p}+x^{-m}+x^{-n}}$$

$$=\frac{x^{-m}+x^{-n}+x^{-p}}{x^{-m}+x^{-n}+x^{-p}}=1$$

Example 7. Solve the equation $a^{-x}(a^x+b^{-x})=\dfrac{a^2b^2+1}{a^2b^2}$

We have $a^{-x}a^x+a^{-x}b^{-x}=1+\dfrac{1}{a^2b^2}$,

or $1+(ab)^{-x}=1+a^{-2}b^{-2}=1+(ab)^{-2}$

Hence, $(ab)^{-x}=(ab)^{-2}$, $\quad x=2$

Example 8. Solve $\left.\begin{aligned} a^x a^{y+1}&=a^7 \quad (1)\\ a^{2y}a^{3x+5}&=a^{20} \quad (2)\end{aligned}\right\}$

[Calcutta University Entrance Paper 1879]

From the 1st equation, we have

$$a^{x+(y+1)}=a^7,$$

$$x+y+1=7 \tag{3}$$

From the 2nd equation, we have

$$a^{2y+(3x+5)}=a^{20}$$

$$2y+3x+5=20 \tag{4}$$

Now from (3) and (4), we have

$$\left.\begin{aligned} x+y-6&=0\\ \text{and}\quad 3x+2y-15&=0\end{aligned}\right\}$$

Therefore, by cross multiplication

$$\frac{x}{-15+12}=\frac{y}{-18+15}=\frac{1}{2-3},$$

or $$\frac{x}{-3}=\frac{y}{-3}=-1$$

Hence, $x=3$ and $y=3$

Example 9. If $a^b=b^a$ show that $\left(\dfrac{a}{b}\right)^{\frac{a}{b}}=a^{\frac{a}{b}-1}$, and if $a=2b$, show that $b=2$

Since $a^b=b^a$,

$a=b^{\frac{a}{b}}$, [extracting the bth root of both sides]

Hence, $\left(\dfrac{a}{b}\right)^{\frac{a}{b}}=\dfrac{a^{\frac{a}{b}}}{b^{\frac{a}{b}}}=\dfrac{a^{\frac{a}{b}}}{a}=a^{\frac{a}{b}-1}$.

If $a=2b$, from the given relation, we have

$(2b)^b=(b)^{2b}=(b^2)^b$, $\quad 2b=b^2$, $\quad b=2$

Example 10. If $x=\left(a+\sqrt{a^2+b^3}\right)^{\frac{1}{3}}+\left(a-\sqrt{a^2+b^3}\right)^{\frac{1}{3}}$, show that $x^3+3bx-2a=0$

Putting m for $a+\sqrt{a^2+b^3}$, and n for $a-\sqrt{a^2+b^3}$, we have

$$\begin{aligned}
x^3&=\left(m^{\frac{1}{3}}+n^{\frac{1}{3}}\right)^3\\
&=\left(m^{\frac{1}{3}}\right)^3+\left(n^{\frac{1}{3}}\right)^3+3m^{\frac{1}{3}}n^{\frac{1}{3}}\left(m^{\frac{1}{3}}+n^{\frac{1}{3}}\right)\\
&=m+n+3(mn)^{\frac{1}{3}}\left(m^{\frac{1}{3}}+n^{\frac{1}{3}}\right)\\
&=m+n+3(mn)^{\frac{1}{3}}x
\end{aligned}$$

But $\quad m+n=2a$

and $\quad (mn)^{\frac{1}{3}}=\{a^2-(a^2+b^3)\}^{\frac{1}{3}}$

$$=(-b^3)^{\frac{1}{3}}=-b\,,$$

$$x^3=2a-3bx \qquad\qquad x^3+3bx-2a=0$$

EXERCISE 104.

Multiply

1. $x^{\frac{2}{3}}+2x^{\frac{1}{2}}+3x^{\frac{1}{3}}+2x^{\frac{1}{6}}+1$ by $x^{\frac{1}{3}}-2x^{\frac{1}{6}}+1$
2. $a^{\frac{2}{3}}+3a^{\frac{1}{3}}b^{\frac{1}{3}}+9b^{\frac{2}{3}}$ by $a^{\frac{1}{3}}-3b^{\frac{1}{3}}$
3. $1+ab^{-1}+a^2b^{-2}$ by $1-ab^{-1}+a^2b^{-2}$
4. $x+2y^{\frac{1}{2}}+3z^{\frac{1}{3}}$ by $x-2y^{\frac{1}{2}}+3z^{\frac{1}{3}}$
5. $x^{-1}+x^{-\frac{1}{2}}y^{-\frac{1}{2}}+y^{-1}$ by $x^{-1}-x^{-\frac{1}{2}}y^{-\frac{1}{2}}+y^{-1}$
6. $a^{\frac{2}{3}}-a^{\frac{1}{3}}+1-a^{-\frac{1}{3}}+a^{-\frac{2}{3}}$ by $a^{\frac{1}{3}}+1+a^{-\frac{1}{3}}$
7. $x^{\frac{2}{3}}+y^{\frac{2}{3}}+z^{\frac{2}{3}}-y^{\frac{1}{3}}z^{\frac{1}{3}}-z^{\frac{1}{3}}x^{\frac{1}{3}}-x^{\frac{1}{3}}y^{\frac{1}{3}}$ by $x^{\frac{1}{3}}+y^{\frac{1}{3}}+z^{\frac{1}{3}}$
8. $a^m+3b^n-2c^p$ by $a^m-3b^n+2c^p$
9. $a^{\frac{5}{2}}+8ab+4a^{\frac{3}{2}}b^{\frac{2}{3}}+2a^2b^{\frac{1}{3}}+32b^{\frac{5}{3}}+16a^{\frac{1}{2}}b^{\frac{4}{3}}$ by $a^{\frac{1}{2}}-2b^{\frac{1}{3}}$
10. $a^{\frac{5}{8}}+a^{\frac{1}{4}}x^{-\frac{3}{8}}+x^{-\frac{5}{8}}+a^{\frac{3}{8}}x^{-\frac{1}{4}}+a^{\frac{1}{8}}x^{-\frac{1}{2}}+a^{\frac{1}{2}}x^{-\frac{1}{8}}$ by

$$a^{\frac{3}{8}}+a^{\frac{1}{8}}x^{-\frac{1}{4}}-x^{-\frac{3}{8}}-a^{\frac{1}{4}}x^{-\frac{1}{8}}$$

Divide

11. $x^{\frac{5}{2}}-4x^{\frac{3}{2}}-2x^{\frac{1}{2}}+6x-x^2$ by $x^{\frac{3}{2}}+2-4x^{\frac{1}{2}}$

12. $8+12x^{-1}+2x^{-2}+2x^{-4}$ by $x^{-2}-2x^{-1}+4$

13. $xy^{-1}+2x^{\frac{1}{2}}y^{-\frac{1}{2}}+3+2x^{-\frac{1}{2}}y^{\frac{1}{2}}+x^{-1}y$ by

$$x^{-1}+x^{-\frac{1}{2}}y^{-\frac{1}{2}}+y^{-1}$$

14. $a^{\frac{5}{2}}-a^{\frac{3}{2}}b+ab^{\frac{3}{2}}-2a^{\frac{1}{2}}b^2+b^{\frac{5}{2}}$ by $a^{\frac{3}{2}}-ab^{\frac{1}{2}}+a^{\frac{1}{2}}b-b^{\frac{3}{2}}$

15. $8x^{-n}-8x^{n}+5x^{3n}-3x^{-3n}$ by $5x^{n}-3x^{-n}$

16. $8x^{\frac{3}{2}}+y^{-\frac{3}{2}}-z+6x^{\frac{1}{2}}y^{-\frac{1}{2}}z^{\frac{1}{3}}$ by $2x^{\frac{1}{2}}+y^{-\frac{1}{2}}-z^{\frac{1}{3}}$

17. Show that $x^3+a^3+x^{\frac{3}{2}}a^{\frac{3}{2}}$ is divisible by $x^{\frac{3}{4}}+a^{\frac{3}{4}}+x^{\frac{3}{8}}a^{\frac{3}{8}}$

18. Multiply $x^{2^{n-1}}+a^{2^{n-1}}$ by $x^{2^{n-1}}-a^{2^{n-1}}$

19. Divide $x^{2^{n}}-y^{2^{n}}$ by $x^{2^{n-1}}+y^{2^{n-1}}$

[C U Entr Paper, 1879]

20. Simplify $\left\{\left(a^{m}\right)^{m-\frac{1}{m}}\right\}^{\frac{1}{m+1}}$.

21. Divide $2x^{-\frac{1}{4}}+3x^{\frac{3}{4}}-7x^{\frac{1}{4}}+x-2x^{\frac{1}{2}}$ by $x^{\frac{1}{4}}-2x^{-\frac{1}{4}}$

22. Find the square of $x^{\frac{3}{4}}-x^{\frac{1}{2}}y^{-\frac{1}{4}}+y^{\frac{1}{2}}$

23. Divide $x^{\frac{3n}{2}}-a^{\frac{3n}{2}}$ by $x^{\frac{n}{2}}-a^{\frac{n}{2}}$

24. Find the square of $x^{\frac{1}{3}}-2x^{\frac{1}{2}}+x^{\frac{5}{6}}$

25. Divide $ax^{-1}+a^{-1}x+2$ by $a^{\frac{1}{3}}x^{-\frac{1}{3}}+a^{-\frac{1}{3}}x^{\frac{1}{3}}-1$

26. Simplify $\left(\dfrac{a-b}{a^{\frac{1}{2}}-b^{\frac{1}{2}}}-\dfrac{a^{\frac{3}{2}}-b^{\frac{3}{2}}}{a-b}\right)^{-1}$

27. Simplify $\dfrac{x^{\frac{1}{3}}+3y^{\frac{1}{3}}}{x^{\frac{1}{3}}-3y^{\frac{1}{3}}}+\dfrac{x^{\frac{2}{3}}-3x^{\frac{1}{3}}y^{\frac{1}{3}}+9y^{\frac{2}{3}}}{x^{\frac{2}{3}}+3x^{\frac{1}{3}}y^{\frac{1}{3}}+9y^{\frac{2}{3}}}$.

28. Simplify $\dfrac{a^{\frac{3}{2}}-ax^{\frac{1}{2}}+a^{\frac{1}{2}}x-x^{\frac{3}{2}}}{a^{\frac{5}{2}}-a^2x^{\frac{1}{2}}+3a^{\frac{3}{2}}x-3ax^{\frac{3}{2}}+a^{\frac{1}{2}}x^2-x^{\frac{5}{2}}}$.

29. Simplify $\dfrac{a^2+b^2-a^{-2}-b^{-2}}{a^2b^2-a^{-2}b^{-2}}+\dfrac{(a-a^{-1})(b-b^{-1})}{ab+a^{-1}b^{-1}}$.

30. Simplify $\dfrac{x-y}{x^{\frac{3}{4}}+x^{\frac{1}{2}}y^{\frac{1}{4}}}-\dfrac{x^{\frac{1}{2}}+y^{\frac{1}{2}}}{x^{\frac{1}{2}}y^{\frac{1}{4}}+x^{\frac{1}{4}}y^{\frac{1}{2}}}$,

31. Simplify

$$(a+b+c)(a^{-1}+b^{-1}+c^{-1})-a^{-1}b^{-1}c^{-1}(b+c)(c+a)(a+b)$$

Solve

32. $2^{x+7}=4^{x+2}$

33. $(\sqrt{3})^{x+5}=(\sqrt[3]{3})^{2x+5}$

34. $(\sqrt[5]{4})^{4x+7}=(\sqrt[11]{64})^{2x+7}$

35. $(\sqrt[3]{25})^{2x+1}=(\sqrt[5]{125})^{x+6}$

36. $\left.\begin{aligned}2^{3x-1}&=4^{y-1}\\ 3x-y&=1\end{aligned}\right\}$

37. $\left.\begin{aligned}9^{2x-3}&=(\sqrt{3})^{2y-x}\\ 2^{3x}&=4^{y}\end{aligned}\right\}$

38. $\left.\begin{aligned}4^{3y-1}&=16^{x+y}\\ 3^{x+3y}&=9^{2x+3}\end{aligned}\right\}$

39. $\left.\begin{aligned}2^{x+y+z}&=8^{x+z-y}\\ 5^{3y+2}&=25^{x+z}\\ 3^{2x+2z+y}&=9^{3x+y}\end{aligned}\right\}$

40. $\left.\begin{aligned}(\sqrt{a})^{x+y}&=(\sqrt[3]{a})^{y+z-1}\\ (\sqrt[3]{b})^{x+z-2}&=(\sqrt[5]{b})^{y+z}\\ (\sqrt[4]{c})^{y}&=(\sqrt[7]{c})^{x+y+1}\end{aligned}\right\}$

CHAPTER XXX

ELEMENTARY SURDS

195. Definition. Any root of any arithmetical number which cannot be exactly found is called a **surd** or an **irrational quantity.** Thus $\sqrt{2}$, $\sqrt{6}$, $\sqrt[3]{4}$ and $\sqrt[4]{5}$ are all surds

Note *Quantities which are not surds are called* ***rational quantities*** *Hence, every root of an arithmetical number is either* ***rational*** *or* ***irrational*** *Thus $\sqrt[3]{8}$, $\sqrt{25}$ and $\sqrt[4]{16}$ are* ***rational quantities,*** *whilst $\sqrt{2}$, $\sqrt[3]{5}$ and $\sqrt[4]{9}$ are all* ***irrational quantities***

An algebraical expression also, such as $\sqrt{x}$ is called a surd, although the value of x may be such that $\sqrt{x}$ is not in reality a surd For instance if $x=4$, $\sqrt{x}=\sqrt{4}=2$ and is therefore not really a surd

196. To express in the form of a surd the product of a rational quantity and a surd.

Example 1. $5\sqrt{3}=(5^2)^{\frac{1}{2}}\times 3^{\frac{1}{2}}$

$=(5^2\times 3)^{\frac{1}{2}}$ [Art 192]

$=\sqrt{5^2\times 3}=\sqrt{75}$

Example 2. $2\sqrt[3]{9}=(2^3)^{\frac{1}{3}}\times 9^{\frac{1}{3}}$

$=(2^3\times 9)^{\frac{1}{3}}$ [Art 190]

$=\sqrt[3]{2^3\times 9}=\sqrt[3]{72}$

EXERCISE 105.

Express as a complete surd

1. $3\sqrt{5}$ **2.** $2\sqrt[3]{3}$ **3.** $2\sqrt[4]{6}$ **4.** $4\sqrt[4]{5}$

5. $a\sqrt[n]{b}$ **6.** $x^3\sqrt[a]{y}$ **7.** $a^4\sqrt[5]{b^2}$

197. A surd may sometimes be expressed as the product of a rational quantity and a surd.

Example 1. $\sqrt{32}=\sqrt{16\times 2}$

$=(4^2\times 2)^{\frac{1}{2}}$

$=(4^2)^{\frac{1}{2}}\times 2^{\frac{1}{2}}$ [Art 192]

$=4\times 2^{\frac{1}{2}}=4\sqrt{2}$

Example 2. $\sqrt[3]{40}=\sqrt[3]{8\times 5}$

$=(2^3\times 5)^{\frac{1}{3}}$

$=(2^3)^{\frac{1}{3}}\times 5^{\frac{1}{3}}$ [Art 192]

$=2\times 5^{\frac{1}{3}}=2\sqrt[3]{5}$

EXERCISE 106.

Simplify

1. $\sqrt{18}$ **2.** $\sqrt{80}$ **3.** $\sqrt[3]{250}$

4. $\sqrt[5]{128}$ **5.** $\sqrt[4]{405}$ **6.** $\sqrt[3]{1372}$

7. $\sqrt[4]{1875}$ **8.** $\sqrt[3]{a^6b}$ **9.** $\sqrt[n]{x^{4n}a}$

10. $\sqrt[3]{-2560}$ **11.** $\sqrt[3]{-192a^3b^4}$ **12.** $\sqrt[3]{500a^7x^4}$

198. Similar Surds. Two or more surds are said to be *similar* when they can be so reduced as to have the same irrational factor Thus $\sqrt{45}$ and $\sqrt{80}$ are similar surds for they are respectively equivalent to $3\sqrt{5}$ and $4\sqrt{5}$ The sum of any number of similar surds may be found as follows

Example 1. $\sqrt{147}+\sqrt{27}$

$$=\sqrt{49\times3}+\sqrt{9\times3}=7\sqrt{3}+3\sqrt{3}=10\sqrt{3}$$

Example 2. $\sqrt[3]{625}-\sqrt[3]{135}+\sqrt[3]{40}$

$$=\sqrt[3]{125\times5}-\sqrt[3]{27\times5}+\sqrt[3]{8\times5}$$
$$=\sqrt[3]{5^3\times5}-\sqrt[3]{3^3\times5}+\sqrt[3]{2^3\times5}$$
$$=5\sqrt[3]{5}-3\sqrt[3]{5}+2\sqrt[3]{5}=4\sqrt[3]{5}.$$

EXERCISE 107.

Simplify

1. $\sqrt{12}+\sqrt{75}$ **2.** $\sqrt{18}+\sqrt{32}$ **3.** $\sqrt{20}+\sqrt{180}$

4. $\sqrt{98}-\sqrt{50}$ **5.** $\sqrt[3]{128}-\sqrt[3]{54}$ **6.** $\sqrt[4]{80}+\sqrt[4]{405}$

7. $\sqrt[4]{768}-\sqrt[4]{243}$ **8.** $2\sqrt{27}-\sqrt{75}+\sqrt{12}$

9. $2\sqrt{405}-3\sqrt{125}+\sqrt{45}$ **10.** $4\sqrt[3]{192}-4\sqrt[3]{375}+2\sqrt[3]{24}$

11. $3\sqrt[3]{40}+2\sqrt[3]{625}-4\sqrt[3]{320}$

12. $5\sqrt[3]{-54}-2\sqrt[3]{-16}+4\sqrt[3]{686}$

13. $\sqrt{45x^3}+\sqrt{80x^3}+\sqrt{5xy^2}$

14. $x\sqrt[3]{x^3a}+y\sqrt[3]{-8y^3a}-z\sqrt[3]{-27z^3a}.$

15. $2\sqrt[4]{32a^4x}+3\sqrt[4]{512a^4x}-4a\sqrt[4]{162x}$

199. Surds of the same order. Surds are said to be *of the same order* or *equiradical* when they have all got the

same root symbol Thus $\sqrt{5}$, $\sqrt{a^3}$ and $(a+x)^{\frac{5}{2}}$ are all surds of the same (*viz* the *second*) order

A surd of the second order is often called a **quadratic surd**; whilst one of the third order, $\sqrt[3]{4}$ or $\sqrt[3]{a^2}$, is called a **cubic surd.**

Surds of different orders may be reduced to equivalent surds of the same order

Example 1. Reduce $\sqrt{5}$ and $\sqrt[3]{4}$ to surds of the same order

The given surds are respectively of the 2nd and 3rd orders, and the L C M of 2 and 3 is 6 Hence, we can at once reduce them to surds of the 6th order, thus

$$\sqrt{5}=5^{\frac{1}{2}}=5^{\frac{3}{6}}=\sqrt[6]{5^3}=\sqrt[6]{125},$$

$$\sqrt[3]{4}=4^{\frac{1}{3}}=4^{\frac{2}{6}}=\sqrt[6]{4^2}=\sqrt[6]{16}$$

Thus the required surds are $\sqrt[6]{125}$ and $\sqrt[6]{16}$

Example 2. Reduce $\sqrt[6]{3}$ and $\sqrt[8]{2}$ to surds of the same order

The L C M of 6 and 8 is 24

Thus we have $\sqrt[6]{3}=3^{\frac{1}{6}}=3^{\frac{4}{24}}=\sqrt[24]{3^4}=\sqrt[24]{81}$,

and $\sqrt[8]{2}=2^{\frac{1}{8}}=2^{\frac{3}{24}}=\sqrt[24]{2^3}=\sqrt[24]{8}$

Thus the required surds are $\sqrt[24]{81}$ and $\sqrt[24]{8}$

Example 3. Which is the greater $\sqrt[3]{9}$ or $\sqrt[4]{20}$?

We have $\sqrt[3]{9}=9^{\frac{1}{3}}=9^{\frac{4}{12}}=\sqrt[12]{9^4}=\sqrt[12]{6561}$

and $\sqrt[4]{20}=20^{\frac{1}{4}}=20^{\frac{3}{12}}=\sqrt[12]{20^3}=\sqrt[12]{8000}$

Thus the given surds are respectively equivalent to $\sqrt[12]{6561}$ and $\sqrt[12]{8000}$, and as the latter is greater than the former, therefore $\sqrt[4]{20}>\sqrt[3]{9}$

EXERCISE 108.

Reduce to surds of the same order

1. $\sqrt{3}$ and $\sqrt[3]{2}$ **2.** $\sqrt[3]{4}$ and $\sqrt[4]{5}$ **3.** $\sqrt[5]{2}$ and $\sqrt[3]{3}$

4. $\sqrt[4]{3}$ and $\sqrt[6]{5}$ **5.** $\sqrt[6]{4}$ and $\sqrt[8]{6}$

Which is the greater

6. $\sqrt{2}$ or $\sqrt[3]{3}$? **7.** $\sqrt[3]{3}$ or $\sqrt[4]{4}$? **8.** $\sqrt[3]{6}$ or $\sqrt[4]{10}$?

Arrange according to descending order of magnitude

9. $\sqrt[4]{6}$, $\sqrt{2}$ and $\sqrt[3]{4}$ **10.** $\sqrt[4]{3}$, $\sqrt[8]{10}$ and $\sqrt[12]{25}$

200. Multiplication and Division of Surds.

Example 1. $\sqrt[3]{6}\times\sqrt[3]{10}=6^{\frac{1}{3}}\times 10^{\frac{1}{3}}$

$$=(6\times 10)^{\frac{1}{3}}=\sqrt[3]{60}$$

Note *In this example the given surds are of the* ***same*** *order*

Example 2. $\sqrt[4]{5}\times\sqrt[6]{8}=5^{\frac{1}{4}}\times 8^{\frac{1}{6}}=5^{\frac{3}{12}}\times 8^{\frac{2}{12}}$

$$=\left(5^3\right)^{\frac{1}{12}}\times\left(8^2\right)^{\frac{1}{12}} \qquad \text{[Art 191]}$$

$$=\left(5^3\times 8^2\right)^{\frac{1}{12}} \qquad \text{[Art 192]}$$

$$=\sqrt[12]{125\times 64}=\sqrt[12]{8000}$$

Note *In this example the given surds are of* ***different*** *orders*

Example 3 $\sqrt[3]{2}\times\sqrt[5]{2}=2^{\frac{1}{3}}\times 2^{\frac{1}{5}}$

$$=2^{\frac{1}{3}+\frac{1}{5}}=2^{\frac{8}{15}}=\sqrt[15]{2^8}=\sqrt[15]{256}$$

Note *In this example the given surds have got the same quantity under the radical sign They may as well be regarded as surds of different orders and treated like those in the last example*

Example 4. $4\sqrt{18}\times\sqrt{75}$

$$=4\,3\sqrt{2}\times 5\sqrt{3}=60\sqrt{2}\,\sqrt{3}=60\sqrt{6}$$

Note *In this example the given surds have been reduced to simpler forms before multiplication*

Example 5. $\sqrt[6]{4}\div\sqrt[4]{6}=4^{\frac{1}{6}}\div 6^{\frac{1}{4}}=4^{\frac{2}{12}}\div 6^{\frac{3}{12}}$

$$=\frac{\left(4^2\right)^{\frac{1}{12}}}{\left(6^3\right)^{\frac{1}{12}}} \qquad \text{[Art 192]}$$

$$=\left(\frac{4^2}{6^3}\right)^{\frac{1}{12}} \qquad [\text{ Cor } 1, \text{ Art } 192]$$

$$=\sqrt[12]{\frac{2}{27}}.$$

Example 6. Express $\sqrt{5}-3\sqrt{3}$ as a fraction with a rational denominator

We have $\sqrt{5}-3\sqrt{3}=\dfrac{\sqrt{5}}{3\sqrt{3}}=\dfrac{\sqrt{5}\times\sqrt{3}}{3\sqrt{3}\times\sqrt{3}}$

$$=\frac{\sqrt{15}}{3\times3}=\frac{\sqrt{15}}{9}.$$

Note *For Arithmetical calculations it is always most convenient to reduce the quotient of one surd by another to the form of a fraction with a rational denominator Hence, even when the numerical value of a surd fraction is not required it is usual to express it in the above form*

EXERCISE 109.

Simplify

1. $\sqrt{5}\times\sqrt{10}$ **2.** $\sqrt{8}\times\sqrt{6}$ **3.** $\sqrt{27}\times\sqrt{3}$

4. $\sqrt{15}\times\sqrt{6}$ **5.** $\sqrt{20}\times\sqrt{45}$ **6.** $\sqrt[3]{5}\times\sqrt[3]{25}$

7. $\sqrt[3]{6ax}\times\sqrt[3]{27a^2x^3}$ **8.** $\sqrt[3]{2}\times\sqrt[2]{6}$ **9.** $\sqrt[2]{2}\times\sqrt[3]{6}$

10. $\sqrt[3]{4}\times\sqrt[2]{8}$ **11.** $\sqrt[3]{9}\times\sqrt[2]{27}$ **12.** $\sqrt[6]{2}\times\sqrt[9]{3}$

13. $\sqrt[4]{3}\times\sqrt[8]{3}$ **14.** $\sqrt[6]{2}\times\sqrt[9]{2}$ **15.** $\sqrt[4]{4}\times\sqrt[6]{4}$

16. $5\sqrt{8}\times2\sqrt{6}$ **17.** $8\sqrt{12}\times3\sqrt{24}$

18. $4\sqrt[3]{72}\times5\sqrt[3]{576}$ **19.** $7\sqrt[3]{8a^3x^2}\times5\sqrt[3]{27b^3x^2}$

20. $8\sqrt{10}\div4\sqrt{15}$ **21.** $3\sqrt{12}-6\sqrt{27}.$

22. $\sqrt[3]{36}-\sqrt[3]{48}$ **23.** $\sqrt[9]{8}-\sqrt[6]{6}$

Given $\sqrt{2}=1\ 414$, $\sqrt{3}=1\ 732$, $\sqrt{5}=2\ 236$, find to 3 places of decimals the numerical value of

24. $\sqrt{2}-\sqrt{6}$ **25.** $\sqrt{72}-\sqrt{40}$ **26.** $\sqrt{275}-\sqrt{22}$

27. $10\sqrt{108}-\sqrt{15}$

201. Compound Surds. An expression consisting of two or more simple surds connected by the sign + or − is called a **compound surd.** Thus, $5\sqrt{2}$ and $4\sqrt{3}$ are simple surds, but $5\sqrt{2}+4\sqrt{3}$ and $5\sqrt{2}-4\sqrt{3}$ are compound surds

Two or more compound surds are multiplied together in the same way as two or more compound algebraical expressions

Example 1. Multiply $\sqrt{x}+2\sqrt{3}$ by $\sqrt{x}-\sqrt{3}$

$$(3\sqrt{x}+2\sqrt{3})(\sqrt{x}-\sqrt{3})=3\sqrt{x}\cdot\sqrt{x}+2\sqrt{3}\cdot\sqrt{x}-3\sqrt{x}\cdot\sqrt{3}-2\sqrt{3}\cdot\sqrt{3}$$
$$=3x+2\sqrt{3x}-3\sqrt{3x}-6=3x-\sqrt{3x}-6$$

Example 2. Multiply $7\sqrt{2}+\sqrt{3}$ by $7\sqrt{2}-\sqrt{3}$

$$(7\sqrt{2}+\sqrt{3})(7\sqrt{2}-\sqrt{3})=(7\sqrt{2})^2-(\sqrt{3})^2$$
$$=49\cdot 2-3=98-3=95$$

Example 3. Find the square of $\sqrt{3a+x}+\sqrt{3a-x}$

$$(\sqrt{3a+x}+\sqrt{3a-x})^2$$
$$=(\sqrt{3a+x})^2+(\sqrt{3a-x})^2+2\sqrt{3a+x}\cdot\sqrt{3a-x}$$
$$=(3a+x)+(3a-x)+2\sqrt{9a^2-x^2}$$
$$=6a+2\sqrt{9a^2-x^2}$$

EXERCISE 110.

Multiply

1. $\sqrt{a}+\sqrt{b}$ by $\sqrt{ab}$ **2.** $\sqrt{a}+\sqrt{b}$ by $\sqrt{a}-\sqrt{b}$

3. $3\sqrt{a}-5$ by $2\sqrt{a}$ **4.** $4\sqrt{x}+3\sqrt{y}$ by $4\sqrt{x}-3\sqrt{y}$.

5. $2\sqrt{x-5}+4$ by $3\sqrt{x-5}-6$

6. $3\sqrt{5}-4\sqrt{2}$ by $2\sqrt{5}+3\sqrt{2}$

7. $\sqrt{2}+2\sqrt{3}+\sqrt{7}$ by $\sqrt{2}+2\sqrt{3}-\sqrt{7}$

8. $3-\sqrt{5}+\sqrt{8}$ by $3-\sqrt{5}-\sqrt{8}$

9. $\sqrt{11}+\sqrt{6}-\sqrt{3}$ by $\sqrt{11}-\sqrt{6}+\sqrt{3}$

10. $\sqrt[3]{4}+\sqrt[3]{9}+\sqrt[3]{48}$ by $\sqrt[3]{2}+\sqrt[3]{3}$

Find the square of

11. $\sqrt{x+a}-\sqrt{x-a}$ **12.** $2\sqrt{8}+5\sqrt{6}$

13. $2\sqrt{5}+3\sqrt{7}$ **14.** $\sqrt{a^2+2b^2}-\sqrt{a^2-2b^2}$

15. $2\sqrt{x^2+y^2}+5\sqrt{x^2-y^2}$

202. Rationalisation. If two surds be such that their product is rational, each of them is said to be rationalised when multiplied by the other Thus $2\sqrt{5}$ and $\sqrt{3}+\sqrt{2}$ are rationalised when respectively multiplied by $\sqrt{5}$ and $\sqrt{3}-\sqrt{2}$

$$\text{for} \qquad 2\sqrt{5}\times\sqrt{5}=10,$$
$$\text{and} \quad (\sqrt{3}+\sqrt{2})(\sqrt{3}-\sqrt{2})=3-2=1$$

Two binomial quadratic surds which differ only in the sign which connects their terms are said to be **conjugate** or **complementary** to each other Thus $\sqrt{3}+\sqrt{2}$ and $2\sqrt{5}-\sqrt{7}$ are respectively *conjugate* (or *complementary*) to $\sqrt{3}-\sqrt{2}$ and $2\sqrt{5}+\sqrt{7}$

Evidently therefore every binomial quadratic surd is rationalised when multiplied by the complementary surd

Hence, a fraction with a binomial quadratic surd for its denominator can be easily reduced to an equivalent fraction with a rational denominator

Example 1. Given $\sqrt{2}=1\cdot414$ find to three places of decimals the value of $\dfrac{1+\sqrt{2}}{3-2\sqrt{2}}$.

$$\frac{1+\sqrt{2}}{3-2\sqrt{2}}=\frac{(1+\sqrt{2})(3+2\sqrt{2})}{(3-2\sqrt{2})(3+2\sqrt{2})}$$
$$=\frac{3+3\sqrt{2}+2\sqrt{2}+4}{9-8}$$
$$=7+5\sqrt{2}$$
$$=7+5\times1\cdot414$$
$$=7+7\cdot070=14\cdot070$$

Example 2. Rationalise the denominator of

$$\frac{\sqrt{1+x^2}-\sqrt{1-x^2}}{\sqrt{1+x^2}+\sqrt{1-x^2}}.$$

The given expression

$$=\frac{(\sqrt{1+x^2}-\sqrt{1-x^2})^2}{(\sqrt{1+x^2}+\sqrt{1-x^2})(\sqrt{1+x^2}-\sqrt{1-x^2})}$$

$$=\frac{(1+x^2)+(1-x^2)-2\sqrt{1-x^4}}{(1+x^2)-(1-x^2)}$$

$$=\frac{2-2\sqrt{1-x^4}}{2x^2}=\frac{1-\sqrt{1-x^4}}{x^2}$$

Example 3 Simplify $\dfrac{3+\sqrt{6}}{5\sqrt{3}-2\sqrt{12}-\sqrt{32}+\sqrt{50}}$

The denominator $=5\sqrt{3}-2\times2\sqrt{3}-4\sqrt{2}+5\sqrt{2}$
$=\sqrt{3}+\sqrt{2}$

Hence, the given fraction $=\dfrac{3+\sqrt{6}}{\sqrt{3}+\sqrt{2}}$

$$=\frac{(3+\sqrt{6})(\sqrt{3}-\sqrt{2})}{(\sqrt{3}+\sqrt{2})(\sqrt{3}-\sqrt{2})}$$

$$=\frac{3\sqrt{3}+3\sqrt{2}-3\sqrt{2}-2\sqrt{3}}{3-2}$$

$$=\sqrt{3}$$

Example 4. Simplify $\dfrac{3\sqrt{2}}{\sqrt{3}+\sqrt{6}}-\dfrac{4\sqrt{3}}{\sqrt{6}+\sqrt{2}}+\dfrac{\sqrt{6}}{\sqrt{2}+\sqrt{3}}$

The 1st term

$$=\frac{3\sqrt{2}}{\sqrt{3}(1+\sqrt{2})}=\frac{\sqrt{6}}{\sqrt{2}+1}=\frac{\sqrt{6}(\sqrt{2}-1)}{(\sqrt{2}+1)(\sqrt{2}-1)}=2\sqrt{3}-\sqrt{6}.$$

The 2nd term

$$=\frac{4\sqrt{3}}{\sqrt{2}(\sqrt{3}+1)}=\frac{2\sqrt{6}}{\sqrt{3}+1}=\frac{2\sqrt{6}(\sqrt{3}-1)}{(\sqrt{3}+1)(\sqrt{3}-1)}$$

$$=\frac{2(3\sqrt{2}-\sqrt{6})}{2}=3\sqrt{2}-\sqrt{6}$$

The 3rd term

$$=\frac{\sqrt{6}}{\sqrt{2}+\sqrt{3}}=\frac{\sqrt{6}(\sqrt{3}-\sqrt{2})}{(\sqrt{3}+\sqrt{2})(\sqrt{3}-\sqrt{2})}=3\sqrt{2}-2\sqrt{3}$$

Hence the given expression

$=(2\sqrt{3}-\sqrt{6})-(3\sqrt{2}-\sqrt{6})+(3\sqrt{2}-2\sqrt{3})$
$=0.$

EXERCISE 111.

Reduce to an equivalent fraction with a rational denominator:

1. $\frac{5\sqrt{3}+\sqrt{7}}{4\sqrt{3}+2\sqrt{7}}$ 2. $\frac{3\sqrt{2}+2\sqrt{3}}{3\sqrt{2}-2\sqrt{3}}$ 3. $\frac{4+3\sqrt{2}}{3-2\sqrt{2}}$.

4. $\frac{3\sqrt{5}+\sqrt{3}}{\sqrt{5}-\sqrt{3}}$ 5. $\frac{\sqrt{a+x}+\sqrt{a-x}}{\sqrt{a+x}-\sqrt{a-x}}$

6. $\frac{\sqrt{x^2+1}-\sqrt{x^2-1}}{\sqrt{x^2+1}+\sqrt{x^2-1}}$ 7. $\frac{1}{1+\sqrt{2}+\sqrt{3}}$.

Given $\sqrt{2}=1.414$ $\sqrt{3}=1.732$ $\sqrt{5}=2.236$, find to three places of decimals the value of

8. $\frac{\sqrt{2}+1}{\sqrt{2}-1}$. 9. $\frac{\sqrt{3}}{2-\sqrt{3}}$. 10. $\frac{8-5\sqrt{2}}{3-2\sqrt{2}}$.

11. $\frac{3}{\sqrt{5}-\sqrt{2}}$ 12. $\frac{3+\sqrt{5}}{3-\sqrt{5}}$. 13. $\frac{\sqrt{5}+\sqrt{3}}{4+\sqrt{15}}$.

Simplify

14. $\frac{1}{x+\sqrt{x^2-1}}+\frac{1}{x-\sqrt{x^2-1}}$.

15. $\frac{15}{\sqrt{10}+\sqrt{20}+\sqrt{40}-\sqrt{5}-\sqrt{80}}$.

16. $\frac{\sqrt{2}(\sqrt{3}+1)(2-\sqrt{3})}{(\sqrt{2}-1)(3\sqrt{3}-5)(2+\sqrt{2})}$.

17. $\frac{4}{\sqrt{3}+\sqrt{5}-\sqrt{2}}$ 18. $(3+2\sqrt{2})^{-3}+(3-2\sqrt{2})^{-3}$

19. $\frac{x+\sqrt{x^2-1}}{x-\sqrt{x^2-1}}-\frac{x-\sqrt{x^2-1}}{x+\sqrt{x^2-1}}$.

20. $\frac{\sqrt{x^2+1}+\sqrt{x^2-1}}{\sqrt{x^2+1}-\sqrt{x^2-1}}+\frac{\sqrt{x^2+1}-\sqrt{x^2-1}}{\sqrt{x^2+1}+\sqrt{x^2-1}}$.

Rationalise the denominator of:

21. $\frac{1}{\sqrt[3]{3}+\sqrt[3]{2}}$ 22. $\frac{1}{\sqrt[3]{4}-\sqrt[3]{3}}$.

203. The square root of a rational quantity can not be partly rational and partly a quadratic surd.

If possible let $\sqrt{n}=a+\sqrt{m}$

Then, squaring both sides, we must have

$$n=a^2+m+2a\sqrt{m},$$

whence, $\sqrt{m}=\dfrac{n-a^2-m}{2a}$.

Thus a surd is equal to a rational quantity, which is impossible

204. If $a+\sqrt{b}=x+\sqrt{y}$, where a and x are rational, and $\sqrt{b}$ and $\sqrt{y}$ are irrational, then will $a=x$ and $b=y$.

For if a be not equal to x, let $a=x+m$,

then we have $x+m+\sqrt{b}=x+\sqrt{y}$,

$$m+\sqrt{b}=\sqrt{y}$$

Thus $\sqrt{y}$ is partly rational and partly a quadratic surd, which is impossible by the last article

Therefore $a=x$, and consequently $\sqrt{b}=\sqrt{y}$, or $b=y$

Note *It should be distinctly borne in mind that the results proved above are true* **only when** *$\sqrt{b}$ and $\sqrt{y}$ are* **really** *irrational For instance, from the relation $5+\sqrt{9}=3+\sqrt{25}$, we cannot conclude that $5=3$ and $9=25$*

205. To find the square root of $a+\sqrt{b}$, where $\sqrt{b}$ is a surd.

Let $\sqrt{a+\sqrt{b}}=\sqrt{x}+\sqrt{y}$

Then, squaring both sides, we have

$$a+\sqrt{b}=x+y+2\sqrt{xy}$$

Hence, by the last article,

$$\left.\begin{aligned} a&=x+y\\ \text{and}\quad \sqrt{b}&=2\sqrt{xy}\end{aligned}\right\}\qquad(1)$$

Hence, $a^2-b=(x+y)^2-4xy$

$$=(x-y)^2,$$

$$\sqrt{a^2-b}=x-y$$

Thus we have $\left.\begin{aligned} x+y&=a\\ \text{and}\quad x-y&=\sqrt{a^2-b}\end{aligned}\right\}$

Hence, by addition and subtraction,

$$2x=a+\sqrt{a^2-b}, \text{ and } 2y=a-\sqrt{a^2-b},$$

$$x=\tfrac{1}{2}(a+\sqrt{a^2-b}),\text{ and }y=\tfrac{1}{2}(a-\sqrt{a^2-b})$$

Thus, $\sqrt{a+\sqrt{b}}=\sqrt{\tfrac{1}{2}(a+\sqrt{a^2-b})}+\sqrt{\tfrac{1}{2}(a-\sqrt{a^2-b})}$

Note. *From the values of x and y found above it is clear that unless $\sqrt{a^2-b}$ is rational the square root obtained is by far more complicated than the original expression Thus the process given above is of no great practical value except when a^2-b is a perfect square*

Cor. From (1), we have $a-\sqrt{b}=x+y-2\sqrt{xy}$

$$=(\sqrt{x}-\sqrt{y})^2,$$

$$\sqrt{a-\sqrt{b}}=\sqrt{x}-\sqrt{y}$$

Thus if $\sqrt{a+\sqrt{b}}=\sqrt{x}+\sqrt{y}$, then will

$$\sqrt{a-\sqrt{b}}=\sqrt{x}-\sqrt{y}.$$

Example 1. Find the square root of $7+2\sqrt{10}$

Let $\sqrt{7+2\sqrt{10}}=\sqrt{x}+\sqrt{y}$

Then squaring both sides,

$$7+2\sqrt{10}=x+y+2\sqrt{xy}$$

Hence
$$\left.\begin{aligned} x+y&=7\\ \text{and}\quad xy&=10\end{aligned}\right\}$$

These relations are evidently satisfied by the numbers 5 and 2

Hence the required root $=\sqrt{5}+\sqrt{2}$

Example 2. Find the square root of $19-8\sqrt{3}$

Let $\sqrt{19-8\sqrt{3}}=\sqrt{x}-\sqrt{y}$

Then $19-8\sqrt{3}=x+y-2\sqrt{xy}$

Hence,
$$\left.\begin{aligned} x+y&=19 && (1)\\ \text{and}\quad 2\sqrt{xy}&=8\sqrt{3},\text{ or } xy=48 && (2)\end{aligned}\right\}$$

Now, (1) and (2) are obviously satisfied by the numbers 16 and 3

Hence, the required root $=\sqrt{16}-\sqrt{3}=4-\sqrt{3}$

Example 3. Find the square root of $16-5\sqrt{7}$

Let $\sqrt{16-5\sqrt{7}}=\sqrt{x}-\sqrt{y}$

Then $16-5\sqrt{7}=x+y-2\sqrt{xy}$

Therefore,
$$\left.\begin{aligned} x+y&=16 \\ \text{and}\quad 2\sqrt{xy}&=5\sqrt{7} \end{aligned}\right\}$$

Hence,
$$\begin{aligned}(x-y)^2&=(x+y)^2-4xy \\ &=(16)^2-(5\sqrt{7})^2=256-175=81,\end{aligned}$$
$$\therefore\quad x-y=9.$$

Thus we have
$$\left.\begin{aligned} x+y&=16 \\ \text{and}\quad x-y&=9 \end{aligned}\right\},$$

Hence, $x=\frac{25}{2}$ and $y=\frac{7}{2}$

Thus the required root $=\sqrt{\frac{25}{2}}-\sqrt{\frac{7}{2}}$

Example 4. Find the square root of $\sqrt{27}+\sqrt{15}$

$$\begin{aligned}\sqrt{27}+\sqrt{15}&=3\sqrt{3}+\sqrt{3}\,\sqrt{5} \\ &=\sqrt{3}(3+\sqrt{5})\end{aligned}$$

Hence, $\sqrt{\sqrt{27}+\sqrt{15}}=\sqrt[4]{3}\,\sqrt{3+\sqrt{5}}.$

Now, proceeding as in the last example, we find that

$$\sqrt{3+\sqrt{5}}=\sqrt{\tfrac{1}{2}}+\sqrt{\tfrac{5}{2}}$$

Therefore $\sqrt{\sqrt{27}+\sqrt{15}}=\sqrt[4]{3}\left(\sqrt{\tfrac{1}{2}}+\sqrt{\tfrac{5}{2}}\right)$

Example 5. Find the value of

$$\frac{1+x}{1+\sqrt{1+x}}+\frac{1-x}{1-\sqrt{1-x}},\ \text{when}\quad x=\frac{\sqrt{3}}{2}.$$

We have

$$1+x=1+\frac{\sqrt{3}}{2}=\frac{2+\sqrt{3}}{2}=\frac{4+2\sqrt{3}}{4}=\left(\frac{\sqrt{3}+1}{2}\right)^2,$$

and $$1-x=1-\frac{\sqrt{3}}{2}=\frac{2-\sqrt{3}}{2}=\frac{4-2\sqrt{3}}{4}=\left(\frac{\sqrt{3}-1}{2}\right)^2.$$

Hence the given expression

$$\begin{aligned}&=\frac{\frac{1}{2}(2+\sqrt{3})}{1+\frac{1}{2}(\sqrt{3}+1)}+\frac{\frac{1}{2}(2-\sqrt{3})}{1-\frac{1}{2}(\sqrt{3}-1)}=\frac{2+\sqrt{3}}{3+\sqrt{3}}+\frac{2-\sqrt{3}}{3-\sqrt{3}} \\ &=\frac{(2+\sqrt{3})(3-\sqrt{3})+(2-\sqrt{3})(3+\sqrt{3})}{(3+\sqrt{3})(3-\sqrt{3})} \\ &=\frac{(6+\sqrt{3}-3)+(6-\sqrt{3}-3)}{9-3}=\frac{6}{6}=1\end{aligned}$$

Example 6. Find the value of

$$\frac{2a\sqrt{1+x^2}}{x+\sqrt{1+x^2}}, \text{ when } x=\frac{1}{2}\left(\sqrt{\frac{a}{b}}-\sqrt{\frac{b}{a}}\right).$$

$$\frac{2a\sqrt{1+x^2}}{x+\sqrt{1+x^2}}=\frac{2a\sqrt{1+x^2}(x-\sqrt{1+x^2})}{x^2-(1+x^2)}$$

$$=-2ax\sqrt{1+x^2}+2a(1+x^2)$$

Now, since $x=\frac{1}{2}\left(\sqrt{\frac{a}{b}}-\sqrt{\frac{b}{a}}\right)$;

$$\therefore\ x^2=\frac{1}{4}\left(\frac{a}{b}+\frac{b}{a}-2\right);$$

$$\therefore\quad \sqrt{1+x^2}=\sqrt{1+\frac{1}{4}\left(\frac{a}{b}+\frac{b}{a}-2\right)}$$

$$=\sqrt{\frac{1}{4}\left(\frac{a}{b}+\frac{b}{a}+2\right)}=\frac{1}{2}\left(\sqrt{\frac{a}{b}}+\sqrt{\frac{b}{a}}\right).$$

Hence, the required value

$$=-2a\frac{1}{4}\left(\frac{a}{b}-\frac{b}{a}\right)+2a\frac{1}{4}\left(\frac{a}{b}+\frac{b}{a}+2\right)$$

$$=2a\left(\frac{1}{2}+\frac{1}{2}\,\frac{b}{a}\right)=a+b$$

EXERCISE 112.

Find the square root of

1. $4-2\sqrt{3}$
2. $7+4\sqrt{3}$
3. $11-6\sqrt{2}$
4. $8+2\sqrt{15}$
5. $14-6\sqrt{5}$
6. $28+10\sqrt{3}$
7. $21-8\sqrt{5}$
8. $17+12\sqrt{2}$
9. $41+12\sqrt{5}$
10. $37-20\sqrt{3}$
11. $31+4\sqrt{21}$
12. $73-12\sqrt{35}$
13. $47+4\sqrt{33}$
14. $4-\sqrt{7}$
15. $6-\sqrt{35}$
16. $\sqrt{18}-\sqrt{16}$
17. $\sqrt{32}-\sqrt{24}$
18. $\sqrt{27}+\sqrt{24}$.
19. $5\sqrt{5}+\sqrt{120}$

20. Simplify $\dfrac{2+\sqrt{3}}{\sqrt{2}+\sqrt{2+\sqrt{3}}}+\dfrac{2-\sqrt{3}}{\sqrt{2}-\sqrt{2-\sqrt{3}}}$.

21. Find the value of $\dfrac{1+x}{1+\sqrt{1+x}}+\dfrac{1-x}{1+\sqrt{1-x}}$, when $x=\dfrac{\sqrt{3}}{2}$.

22. Find the value of $\dfrac{\sqrt{a+x}+\sqrt{a-x}}{\sqrt{a+x}-\sqrt{a-x}}$, when $x=\dfrac{2ab}{b^2+1}$.

Find the square root of

23. $a^2+2x\sqrt{a^2-x^2}$

24. $2a+2\sqrt{a^2-b^2}$

25. $a+x+\sqrt{2ax+x^2}$

26. $2x-1+2\sqrt{x^2-x-6}$

27. $x+y+z+2\sqrt{xz+yz}$

206. Equations involving Surds.

Example 1. Solve $\sqrt{x+12}=\sqrt{x}+2$

Squaring both sides, we have

$$x+12=x+4+4\sqrt{x}$$

Hence, $4\sqrt{x}=8$,

or, $\sqrt{x}=2$, $\therefore\ x=4$

Example 2. Solve $2(x+2)=1+\sqrt{4x^2+9x+14}$

[C U Entr Paper, 1877]

By transposition, we have

$$2x+3=\sqrt{4x^2+9x+14}$$

Squaring both sides,

$$4x^2+12x+9=4x^2+9x+14,$$

or, $3x=5$, $\therefore\ x=\frac{5}{3}$

Example 3. Solve $\sqrt{x+6}+\sqrt{x-5}=11$

By transposition, $\sqrt{x+6}=11-\sqrt{x-5}$.

Squaring both sides, $x+6=121-22\sqrt{x-5}+(x-5)$

$22\sqrt{x-5}=110$, [by transposition]

or, $\sqrt{x-5}=5$,

$x-5=25$, . $x=30$

Example 4. Solve $\sqrt{x^2+11x+20}-\sqrt{x^2+5x-1}=3$

[C U Entr Paper, 1881.]

By transposition,

$$\sqrt{x^2+11x+20}=3+\sqrt{x^2+5x-1}$$

Squaring both sides,

$$x^2+11x+20=9+(x^2+5x-1)+6\sqrt{x^2+5x-1},$$

or, $6x+12=6\sqrt{x^2+5x-1},$

or, $x+2=\sqrt{x^2+5x-1},$

$x^2+4x+4=x^2+5x-1,$ whence $x=5$

Example 5. Solve $\dfrac{3x-1}{\sqrt{3x}+1}=1+\dfrac{\sqrt{3x}-1}{2}.$

Since $3x-1=(\sqrt{3x}+1)(\sqrt{3x}-1);$

$$\frac{3x-1}{\sqrt{3x}+1}=\sqrt{3x}-1$$

Hence, from the given equation, we have

$$\sqrt{3x}-1=1+\frac{\sqrt{3x}-1}{2},$$

or, $(\sqrt{3x}-1)(1-\frac{1}{2})=1,$ [by transposition,]

or, $\dfrac{\sqrt{3x}-1}{2}=1,$

or, $\sqrt{3x}-1=2,$

or, $\sqrt{3x}=3,$ $\therefore$ $3x=9$; $\therefore$ $x=3.$

Example 6. Solve $\sqrt[3]{a+x}+\sqrt[3]{a-x}=b$

Since $(\sqrt[3]{a+x}+\sqrt[3]{a-x})^3$

$$=(a+x)+(a-x)+3\sqrt[3]{a^2-x^2}\{\sqrt[3]{a+x}+\sqrt[3]{a-x}\}$$

$$=2a+3\sqrt[3]{a^2-x^2}\,b,$$

therefore, cubing both sides of the equation, we have

$$2a+3\sqrt[3]{a^2-x^2}\,b=b^3$$

or, $3b\sqrt[3]{a^2-x^2}=b^3-2a,$ $\therefore$ $a^2-x^2=\left(\dfrac{b^3-2a}{3b}\right)^3;$

$$x^2=a^2-\left(\frac{b^3-2a}{3b}\right)^3;$$

$$x=\sqrt{a^2-\left(\frac{b^3-2a}{3b}\right)^3}.$$

Example 7. Solve $\dfrac{x-8}{\sqrt{x+1}-3}+\dfrac{x-26}{\sqrt{x-1}+5}=\dfrac{4x-5}{\sqrt{4x-1}+2}$.

$$\frac{x-8}{\sqrt{x+1}-3}=\frac{(x-8)(\sqrt{x+1}+3)}{(x+1)-9}=\sqrt{x+1}+3,$$

$$\frac{x-26}{\sqrt{x-1}+5}=\frac{(x-26)(\sqrt{x-1}-5)}{(x-1)-25}=\sqrt{x-1}-5;$$

$$\frac{4x-5}{\sqrt{4x-1}+2}=\frac{(4x-5)(\sqrt{4x-1}-2)}{(4x-1)-4}=\sqrt{4x-1}-2$$

Hence, from the given equation, we have

$$(\sqrt{x+1}+3)+(\sqrt{x-1}-5)=\sqrt{4x-1}-2,$$

or, $\quad \sqrt{x+1}+\sqrt{x-1}=\sqrt{4x-1},$

$\therefore \quad (x+1)+(x-1)+2\sqrt{x^2-1}=4x-1,$

or, $\quad 2\sqrt{x^2-1}=2x-1,$

or, $\quad 4(x^2-1)=4x^2-4x+1,$

or, $\quad 4x=5, \quad \therefore x=\frac{5}{4}.$

Example 8. Solve $\sqrt{2x^2+9}+\sqrt{2x^2-9}=9+3\sqrt{7}$.

We have, for *all* values of x,

$$(2x^2+9)-(2x^2-9)=18,$$

and hence, this relation is also true for the particular value which x has in the given equation.

Therefore, the required value of x will also satisfy the equation

$$\frac{(2x^2+9)-(2x^2-9)}{\sqrt{2x^2+9}+\sqrt{2x^2-9}}=\frac{18}{9+3\sqrt{7}},$$

or, $\quad \sqrt{2x^2+9}-\sqrt{2x^2-9}=\dfrac{18(9-3\sqrt{7})}{81-63}=9-3\sqrt{7}.$

Adding together the given equation and this, we have

$$2\sqrt{2x^2+9}=18,$$

or, $$\sqrt{2x^2+9}=9,$$

$\therefore$ $$2x^2+9=81,$$

$$x^2=36, \qquad x=6$$

EXERCISE 113.

Solve the following equations

1. $\sqrt{x+7}=1+\sqrt{x}$ **2.** $\sqrt{3x+16}=\sqrt{3x}+2$

3. $\sqrt{x+9}=1+\sqrt{x}$ **4.** $\sqrt{3x}-4=\sqrt{3x+4}$

5. $\sqrt{5x+10}=\sqrt{5x}+2$ **6.** $\sqrt{x-16}+\sqrt{x}=8$

7. $\sqrt{2x+9}+\sqrt{2x}=9$ **8.** $\sqrt{x+11}-\sqrt{x}=1$

9. $\sqrt{8x+33}-3=2\sqrt{2x}$ **10.** $x+\sqrt{2ax+x^2}=a$

11. $x+a+\sqrt{2ax+x^2}=b$ **12.** $\sqrt{x-4}+3=\sqrt{x+11}$.

13. $\sqrt{x-5}=6-\sqrt{x+7}$ **14.** $\sqrt{x+9}-\sqrt{x+2}=1$

15. $\sqrt{3x+1}-\sqrt{3x-11}=2$ **16.** $\sqrt{5x+6}+\sqrt{5x-14}=10$.

17. $\sqrt{7x+4}+\sqrt{7x-12}=8$

18. $\sqrt{x^2-3x+5}-\sqrt{x^2-x+1}=1$

19. $\dfrac{x-1}{\sqrt{x}+1}=4+\dfrac{\sqrt{x}-1}{2}$. **20.** $\dfrac{ax-1}{\sqrt{ax}+1}=4+\dfrac{\sqrt{ax}-1}{2}$.

[C U Entr Paper, 1885]

21. $\dfrac{ax-b^2}{\sqrt{ax}+b}=c+\dfrac{\sqrt{xa}-b}{c}$.

22. $\dfrac{200+120\sqrt{5x}}{9x-5}=(3\sqrt{x}-\sqrt{5})^2$

23. $\sqrt{4a+x}-\sqrt{a+x}=2\sqrt{x-2a}$

24. $\sqrt{x}+\sqrt{a+x}=\dfrac{3a}{\sqrt{a+x}}$. **25.** $\sqrt{x}+\sqrt{x+13}=\dfrac{91}{\sqrt{x+13}}$.

26. $\sqrt{x+a}+\sqrt{x-a}=\dfrac{b}{\sqrt{x+a}}$.

27. $\dfrac{3\sqrt{x}-4}{\sqrt{x}+2}=\dfrac{15+3\sqrt{x}}{\sqrt{x}+40}$. 28. $\sqrt{x}+\sqrt{x-\sqrt{1-x}}=1$

29. $\sqrt{x}+\sqrt{8-\sqrt{x^2+8x}}=2\sqrt{2}$

30. $\sqrt{1-x}+\sqrt{1-x+\sqrt{1+x}}=\sqrt{1+x}$

31. $\dfrac{1}{a}\sqrt{a+x}+\dfrac{1}{x}\sqrt{a+x}=\dfrac{1}{b}\sqrt{x}$

32. $\sqrt[5]{x+8}=\sqrt[10]{x^2+64x+36}$

33. $(1+x)^{\frac{1}{3}}+(1-x)^{\frac{1}{3}}=2^{\frac{1}{3}}$ [C U Entr Paper 1885]

34. $(a+x)^{\frac{2}{3}}+(a-x)^{\frac{2}{3}}=3(a^2-x^2)^{\frac{1}{3}}$

35. $\left(\dfrac{x}{a}+\dfrac{a}{b}\right)^{\frac{1}{2}}+9\left(\dfrac{x}{a}-\dfrac{a}{b}\right)^{\frac{1}{2}}=6\left(\dfrac{x^2}{a^2}-\dfrac{a^2}{b^2}\right)^{\frac{1}{4}}$.

36. $\dfrac{x-47}{\sqrt{x+2}-7}+\dfrac{x-19}{\sqrt{x-3}-4}=\dfrac{4x-124}{\sqrt{4x-3}-11}$.

37. $\dfrac{2x-49}{\sqrt{2x+15}-8}+\dfrac{18x+22}{\sqrt{18x+31}+3}=\dfrac{8x+191}{2\sqrt{2x+54}-5}$.

38. $x=\sqrt{a^2+x\sqrt{b^2+x^2}}-a$

39. $\sqrt{x^2+9}+\sqrt{x^2-9}=4+\sqrt{34}$

40. $\sqrt{3x^2+16}-\sqrt{3x^2-16}=8-4\sqrt{2}$

CHAPTER XXXI

EVOLUTION: SQUARE AND CUBE ROOTS.

207. Evolution. The process of finding the roots of quantities is called **Evolution.**

Thus, evolution is the inverse of Involution [Art 127]

208. The ordinary method of finding the square root of a compound algebraical expression. From our previous knowledge of formulæ the following results are obvious

$$(a+b)^2 = a^2 + (2a+b)b,$$
$$(a+b+c)^2 = a^2 + (2a+b)b + (2a+2b+c)c,$$
$$(a+b+c+d)^2 = a^2 + (2a+b)b + (2a+2b+c)c + (2a+2b+2c+d)d;$$

and so on

Clearly therefore we must have

$(ax^2+bx+c)^2 = a^2x^4 + (2ax^2+bx)bx + (2ax^2+2bx+c)c$, and this latter, when arranged according to the descending powers of x, $= a^2x^4 + 2abx^3 + (b^2+2ac)x^2 + 2bcx + c^2$

Now if it is proposed to find the square root of the above expression, let us see what means we have of discovering successively the several terms of the root.

The first term of the root, *viz*, ax^2, is evidently the square root of the first term of the given expression which is a^2x^4;

if we subtract a^2x^4 from the given expression, the remainder is $\{(2ax^2+bx)bx + (2ax^2+2bx+c)c\}$, in which the term containing the highest power of $x = 2ax^2 \times bx$, *i e*, = twice the first term of the root *into* the second term; this enables us to get the second term after having obtained the first,

if now from the above remainder we subtract $(2ax^2+bx) \times bx$, the second remainder is $(2ax^2+2bx+c)c$, in which the term containing the highest power of $x = 2ax^2 \times c$, *i e*, = twice the first term of the root *into* the third; this shows how to get the 3rd term after having obtained the 1st and 2nd

Thus we are furnished with a clue for successively discovering the terms of the expression ax^2+bx+c when its square is given

The operation may be performed as follows

$$\begin{array}{lll}
 & a^2x^4 + 2abx^3 + (b^2+2ac)x^2 + 2bcx + c^2 & (ax^2+bx+c \\
 & a^2x^4 & \\
\hline
2ax^2+bx & 2abx^3 + (b^2+2ac)x^2 + 2bcx + c^2 & \\
 & 2abx^3 + b^2x^2 & \\
\hline
2ax^2+2bx+c & 2acx^2 + 2bcx + c^2 & \\
 & 2acx^2 + 2bcx + c^2 &
\end{array}$$

(1) Find the square root of a^2x^4, the first term of the proposed expression, and set it down as the first term of the required root,

(2) subtract a^2x^4 from the given expression, and bring down the remainder $2abx^3+(b^2+2ac)x^2+2bcx+c^2$;

(3) set down $2ax^2$, i e. twice the 1st term of the root, on the left of the above remainder as the first term of a divisor;

(4) divide the first term of the remainder by $2ax^2$ and set down the quotient, bx, as the second term of the root and also as the second term of the divisor;

(5) multiply the divisor thus obtained by the second term of the root and subtract the product from the first remainder;

(6) bring down the second remainder $2acx^2+2bcx+c^2$ and put $2ax^2+2bx$ (i e, twice the sum of the two terms of the root already obtained) on the left of this remainder for the first two terms of a divisor;

(7) divide the first term of the new remainder by the first term of the new divisor and set down the quotient, c, as the third term of the root and also as the third term of the divisor;

(8) multiply the complete divisor thus obtained by the third term of the root and subtract the product from the second remainder

After this nothing remains, and we obtain ax^2+bx+c for the required root.

Note. *The expression considered above stands arranged according to descending powers of x Similarly, every expression of which the square root is sought must be arranged according to descending or ascending order of the power of the same letter*

Example 1. Extract the square root of

$$x^6+8x^4-2x^3+16x^2-8x+1.$$

$$\begin{array}{r|l}
 & x^6+8x^4-2x^3+16x^2-8x+1\;(x^3+4x-1 \\
 & \underline{x^6\qquad\qquad\qquad\qquad\qquad\qquad} \\
2x^3+4x & 8x^4-2x^3+16x^2-8x+1 \\
 & \underline{8x^4\qquad\quad+16x^2\qquad\quad} \\
2x^3+8x-1 & -2x^3\qquad\qquad-8x+1 \\
 & \underline{-2x^3\qquad\qquad-8x+1}
\end{array}$$

Thus the required root $=x^3+4x-1$

Example 2. Extract the square root of $x^4+2(y+z)x^3+(3y^2+2yz+3z^2)x^2+2(y^3+y^2z+yz^2+z^3)x+y^4+2y^2z^2+z^4$

[C U Entr Paper, 1888]

The given expression

$$=x^4+2(y+z)x^3+(3y^2+2yz+3z^2)x^2$$
$$+2(y+z)(y^2+z^2)x+(y^2+z^2)^2$$

which stands arranged according to descending powers of x; so we can at once proceed thus

$$\begin{array}{l|l}
 & x^4+2(y+z)x^3+(3y^2+2yz+3z^2)x^2+2(y+z)(y^2+z^2)x+(y^2+z^2)^2 \;\big(\, x^2+(y+z)x+(y^2+z^2) \\
 & x^4 \\
\hline
2x^2+(y+z)x & 2(y+z)x^3+(3y^2+2yz+3z^2)x^2 \\
 & 2(y+z)x^3+(\ \ y^2+2yz+\ \ z^2)x^2 \\
\hline
2x^2+2(y+z)x+(y^2+z^2) & 2(y^2+z^2)x^2+2(y+z)(y^2+z^2)x+(y^2+z^2)^2 \\
 & 2(y^2+z^2)x^2+2(y+z)(y^2+z^2)x+(y^2+z^2)^2 \\
\hline
\end{array}$$

Thus the required root $=x^2+xy+xz+y^2+z^2$

Example 3. Find the square root of

$$\frac{x^4}{4}+4x^2+\frac{ax^2}{3}+\frac{a^2}{9}-2x^3-\frac{4ax}{3}.$$ [C U Entr Paper, 1889]

Arrange the expression according to descending powers of x and then proceed thus

$$\begin{array}{l|l}
 & \frac{x^4}{4}-2x^3+4x^2+\frac{ax^2}{3}-\frac{4ax}{3}+\frac{a^2}{9}\Big(\frac{x^2}{2}-2x+\frac{a}{3} \\
 & \frac{x^4}{4} \\
\hline
x^2-2x & -2x^3+4x^2 \\
 & -2x^3+4x^2 \\
\hline
x^2-4x+\frac{a}{3} & \frac{ax^2}{3}-\frac{4ax}{3}+\frac{a^2}{9} \\
 & \frac{ax^2}{3}-\frac{4ax}{3}+\frac{a^2}{9} \\
\hline
\end{array}$$

Thus the required root $=\frac{x^2}{2}-2x+\frac{a}{3}$.

Example 4. Extract the square root of

$$\frac{x^4}{4y^4}+\frac{4y^4}{x^4}+\frac{x^2}{y^2}+\frac{4y^2}{x^2}+3$$

The expression when arranged according to descending powers of x stands thus

$$\frac{x^4}{4y^4}+\frac{x^2}{y^2}+3+\frac{4y^2}{x^2}+\frac{4y^4}{x^4},$$

for *now* the indices of the powers of x in the successive terms are respectively 4, 2, 0, -2 and -4, which numbers evidently are in descending order of magnitude Hence, we proceed as follows.

$$\begin{array}{l}
\frac{x^4}{4y^4}+\frac{x^2}{y^2}+3+\frac{4y^2}{x^2}+\frac{4y^4}{x^4}\Big(\frac{x^2}{2y^2}+1+\frac{2y^2}{x^2}\\
\frac{x^4}{4y^4}\\
\hline
\frac{x^2}{y^2}+1\Big)\frac{x^2}{y^2}+3\\
\qquad\qquad\frac{x^2}{y^2}+1\\
\hline
\frac{x^2}{y^2}+2+\frac{2y^2}{x^2}\Big)2+\frac{4y^2}{x^2}+\frac{4y^4}{x^4}\\
\qquad\qquad\qquad\qquad 2+\frac{4y^2}{x^2}+\frac{4y^4}{x^4}.\\
\hline
\end{array}$$

Thus the required root $=\frac{x^2}{2y^2}+1+\frac{2y^2}{x^2}$.

Example 5. Extract the square root of

$$x^{\frac{8}{5}}-2a^{-\frac{3}{5}}x^{\frac{11}{5}}+2a^{\frac{4}{5}}x^{\frac{4}{5}}+a^{-\frac{6}{5}}x^{\frac{14}{5}}-2a^{\frac{1}{5}}x^{\frac{7}{5}}+a^{\frac{8}{5}}$$

[C U Entr Paper, 1880]

Let us proceed by arranging the expression according to descending powers of x, thus

$$\begin{array}{l}
a^{-\frac{6}{5}}x^{\frac{14}{5}}-2a^{-\frac{3}{5}}x^{\frac{11}{5}}+x^{\frac{8}{5}}-2a^{\frac{1}{5}}x^{\frac{7}{5}}+2a^{\frac{4}{5}}x^{\frac{4}{5}}+a^{\frac{8}{5}}\Big(a^{-\frac{3}{5}}x^{\frac{7}{5}}-x^{\frac{4}{5}}-a^{\frac{4}{5}}\\
a^{-\frac{6}{5}}x^{\frac{14}{5}}\\
\hline
2a^{-\frac{3}{5}}x^{\frac{7}{5}}-x^{\frac{4}{5}}\Big)-2a^{-\frac{3}{5}}x^{\frac{11}{5}}+x^{\frac{8}{5}}\\
\qquad\qquad\quad -2a^{-\frac{3}{5}}x^{\frac{11}{5}}+x^{\frac{8}{5}}\\
\hline
2a^{-\frac{3}{5}}x^{\frac{7}{5}}-2x^{\frac{4}{5}}-a^{\frac{4}{5}}\Big)-2a^{\frac{1}{5}}x^{\frac{7}{5}}+2a^{\frac{4}{5}}x^{\frac{4}{5}}+a^{\frac{8}{5}}\\
\qquad\qquad\qquad\qquad -2a^{\frac{1}{5}}x^{\frac{7}{5}}+2a^{\frac{4}{5}}x^{\frac{4}{5}}+a^{\frac{8}{5}}\\
\hline
\end{array}$$

Thus the required root $=a^{-\frac{3}{5}}x^{\frac{7}{5}}-x^{\frac{4}{5}}-a^{\frac{4}{5}}$.

EXERCISE 114.

Find the square root of

1. $4x^2z^2+12xyz+9y^2$ 2. $x^4-4x^3+10x^2-12x+9$
3. $x^6-2x^4+2x^3+x^2-2x+1$
4. $4x^4-12x^3+25x^2-24x+16$
5. $4x^4+8ax^3+4a^2x^2+16b^2x^2+16ab^2x+16b^4$.
[C U Entr Paper, 1870]
6. $9x^4-2x^3y+\frac{163}{9}x^2y^2-2xy^3+9y^4$
[C U Entr Paper, 1874]
7. $x^4-2x^3+\dfrac{3x^2}{2}-\dfrac{x}{2}+\dfrac{1}{16}$.
8. $\dfrac{1051x^2}{25}-\dfrac{6x}{5}-\dfrac{14x^3}{5}+49x^4+9$
9. $x^4+\dfrac{4}{x^2}-2+4x-x^3+\dfrac{x^2}{4}$.
10. $\dfrac{a^2}{x^2}+\dfrac{x^2}{a^2}+\dfrac{a^4}{4}+\dfrac{a^3}{x}-2-ax$
11. $\dfrac{a^2}{4b^2}-\dfrac{a}{b}+\dfrac{4b^2}{a^2}-1+\dfrac{4b}{a}$.
12. $\dfrac{9a^2}{x^2}-\dfrac{6a}{5x}+\dfrac{101}{25}-\dfrac{4x}{15a}+\dfrac{4x^2}{9a^2}$.
13. $4x^4-8x^3y^2+4xy^6+y^8$.
14. $\dfrac{49x^2}{y^2}+\dfrac{y^2}{49x^2}-\dfrac{42x}{y}+\dfrac{6y}{7x}+7$
15. $\dfrac{x^2}{y^2}+\dfrac{y^2}{x^2}-\dfrac{x}{y}+\dfrac{y}{x}-1\frac{3}{4}$
16. $25\frac{3}{7}-\dfrac{20x}{7y}+\dfrac{9y^2}{16x^2}-\dfrac{15y}{2x}+\dfrac{4x^2}{49y^2}$.
17. $x^2-2x^{\frac{3}{2}}+3x-2x^{\frac{1}{2}}+1$
18. $x^{\frac{5}{3}}-4x^{\frac{4}{3}}+2x+4x^{\frac{2}{3}}+x^{\frac{1}{3}}$
19. $a^2x^{-2}+2ax^{-1}+a^{-2}x^2+3+2a^{-1}x$
20. $x^{\frac{3}{2}}+xy^{-\frac{1}{2}}-2x^{\frac{5}{4}}y^{-\frac{1}{4}}-2x^{\frac{1}{2}}y^{\frac{1}{4}}+2x^{\frac{3}{4}}y^{\frac{1}{2}}+y$

21. $\frac{9x^3}{4} - 5x^{\frac{5}{2}}y^{\frac{1}{2}} + \frac{179x^2y}{45} - \frac{4x^{\frac{3}{2}}y^{\frac{3}{2}}}{3} + \frac{4xy^2}{25}$.

22. $a^{2m} - 4a^{m+n} + 4a^{2n}$

23. $9a^{2m} + 6a^{3m+1} + 25c^{2m-4} - 30a^m c^{m-2} + a^{4m+2} - 10a^{2m+1}c^{m-2}$.

209. Extraction of square roots by the application of the formula $a^2 \pm 2ab + b^2 = (a \pm b)^2$.

Example 1. Find the square root of

$4 - 4c + 2b + c^2 - bc + \frac{b^2}{4}$. [C U Entr Paper, 1876]

The given expression according to powers of b,

$$= \frac{b^2}{4} - b(c-2) + (c^2 - 4c + 4)$$

$$= \left(\frac{b}{2}\right)^2 - 2\left\{\frac{b}{2}(c-2)\right\} + (c-2)^2$$

$$= \left\{\frac{b}{2} - (c-2)\right\}^2 = \left(\frac{b}{2} - c + 2\right)^2.$$

Therefore the reqd root $= \frac{b}{2} - c + 2$

Example 2. Extract the square root of

$$\left(x^2 + \frac{1}{x^2}\right)^2 - 4\left(x + \frac{1}{x}\right)^2 + 12$$

The given expression

$$= \left(x^2 + \frac{1}{x^2}\right)^2 - 4\left(x^2 + \frac{1}{x^2} + 2\right) + 12$$

$$= \left(x^2 + \frac{1}{x^2}\right)^2 - 4\left(x^2 + \frac{1}{x^2}\right) + 4 = \left(x^2 - 2 + \frac{1}{x^2}\right)^2.$$

Therefore the required root $= x^2 - 2 + \frac{1}{x^2}$.

Example 3. Extract the square root of

$\frac{(a^2+b^2)^2}{a^4+b^4-2a^2b^2} + 4\frac{a}{a+b} \times \frac{b}{a-b}$. [C U Entr Paper, 1886]

The given expression

$$= \frac{(a^2+b^2)^2}{(a^2-b^2)^2} + \frac{4ab}{a^2-b^2} = \frac{(a^2+b^2)^2 + 4ab(a^2-b^2)}{(a^2-b^2)^2},$$

of which the numerator $=\{(a^2-b^2)^2+4a^2b^2\}+4ab(a^2-b^2)$

$$=(a^2-b^2)^2+4ab(a^2-b^2)+4a^2b^2$$
$$=\{(a^2-b^2)+2ab\}^2,$$

the given expression $=\dfrac{(a^2+2ab-b^2)^2}{(a^2-b^2)^2}$.

Therefore the reqd root $=\dfrac{a^2+2ab-b^2}{a^2-b^2}$.

Example 4. Extract the square root of

$(ab+ac+bc)^2-4abc(a+c)$ [C U Entr Paper, 1888]

The given expression

$$=\{b(a+c)+ac\}^2-4abc(a+c)$$
$$=b^2(a+c)^2+a^2c^2-2abc(a+c)$$
$$=\{b(a+c)-ac\}^2=(ab-ac+bc)^2$$

Therefore the required root $=ab-ac+bc$

Example 5. Extract the square root of

$$a^4+b^4+c^4+d^4-2(a^2+c^2)(b^2+d^2)+2a^2c^2+2b^2d^2$$

Arranging the given expressions according to descending powers of a, we have

$$a^4-2a^2(b^2+d^2-c^2)+\{b^4+c^4+d^4-2c^2(b^2+d^2)+2b^2d^2\},$$

and the expression within the braces arranged according to descending powers of b,

$$=b^4-2b^2(c^2-d^2)+(c^4+d^4-2c^2d^2)$$
$$=b^4-2b^2(c^2-d^2)+(c^2-d^2)^2$$
$$=\{b^2-(c^2-d^2)\}^2$$

Hence, the given expression

$$=a^4-2a^2(b^2-c^2+d^2)+(b^2-c^2+d^2)^2$$
$$=\{a^2-(b^2-c^2+d^2)\}^2$$
$$=(a^2-b^2+c^2-d^2)^2$$

Therefore the required root $=a^2-b^2+c^2-d^2$

Example 6. Find the square root of

$$4\{(a^2-b^2)cd+ab(c^2-d^2)\}^2+\{(a^2-b^2)(c^2-d^2)-4abcd\}^2$$

The given expression

$$=4\{(a^2-b^2)^2c^2d^2+2abcd(a^2-b^2)(c^2-d^2)+a^2b^2(c^2-d^2)^2\}$$
$$+\{(a^2-b^2)^2(c^2-d^2)^2-8abcd(a^2-b^2)(c^2-d^2)+16a^2b^2c^2d^2\}$$

$=\{4(a^2-b^2)^2c^2d^2+4a^2b^2(c^2-d^2)^2\}+\{(a^2-b^2)^2(c^2-d^2)^2$
$+16a^2b^2c^2d^2\}$
$=(a^2-b^2)^2\{(c^2-d^2)^2+4c^2d^2\}+4a^2b^2\{(c^2-d^2)^2+4c^2d^2\}$
$=\{(a^2-b^2)^2+4a^2b^2\}\{(c^2-d^2)^2+4c^2d^2\}$
$=(a^4+2a^2b^2+b^4)(c^4+2c^2d^2+d^4)$
$=(a^2+b^2)^2(c^2+d^2)^2$

Therefore the required root $=(a^2+b^2)(c^2+d^2)$

EXERCISE 115.

Find the square root of

1. $25x^2y^2-40xy+16$

2. $49a^2x^4-42ab^2x^2+9b^4$

3. $49a^6b^8+126a^7b^7+81a^8b^6$

4. $\frac{1}{4}x^8y^4-\frac{1}{5}x^7y^7+\frac{1}{25}x^6y^{10}$

5. $\frac{25a^2b^2}{4}+\frac{c^4}{9}-\frac{5abc^2}{3}$.

6. $a^2+b^2+c^2+2ab+2ac+2bc$

7. $a^2+b^2+c^2-2ab+2ac-2bc$.

8. $4a^2+b^2+9c^2+6bc-12ac-4ab$

9. $a^4+4b^4+9c^4+4a^2b^2-6a^2c^2-12b^2c^2$

10. $4a^4+9b^4+25c^4-12a^2b^2+20a^2c^2-30b^2c^2$

11. $x^2+\frac{a^2}{9}-bx+\frac{b^2}{4}-\frac{ab}{3}+\frac{2ax}{3}$.

12. $\left(x+\frac{1}{x}\right)^2-4\left(x-\frac{1}{x}\right)$.

13. $x^4+\frac{1}{x^4}+2\left(x^2+\frac{1}{x^2}\right)+3$

14. $\frac{a^2}{b^2}+\frac{b^2}{a^2}+\frac{2a}{b}+\frac{2b}{a}+3$

15. $\frac{x^2}{y^2}+\frac{y^2}{x^2}-\left(\frac{x}{y}+\frac{y}{x}\right)\sqrt{2}+2\frac{1}{2}$

16. $\frac{9x^2}{a^2}+\frac{a^2}{9x^2}-6\frac{x}{a}-\frac{2a}{3x}+3$

17. $x^2+\frac{1}{x^2}+4\left(x+\frac{1}{x}\right)+6$

18. $-2+a^{\sqrt[2]{2}}+a^{-\sqrt[2]{2}}$.

19. $a^2+b^2+c^2+d^2-2a(b-c+d)-2b(c-d)-2cd$

20. $(a-b)^4-2(a^2+b^2)(a-b)^2+2(a^4+b^4)$

21. $a^4+b^4+c^4+d^4-2a^2(b^2+d^2)-2b^2(c^2-d^2)+2c^2(a^2-d^2)$.

22. $a^4+2a^3-a+\frac{1}{4}$

23. $2a^2(b+c)^2+2b^2(c+a)^2+2c^2(a+b)^2+4abc(a+b+c)$

210. The ordinary method of finding the cube root of a compound algebraical expression.

Evidently we have $(ax^2+bx+c)^3$

$$=(ax^2+bx)^3+3(ax^2+bx)^2c+3(ax^2+bx)c^2+c^3$$
$$=a^3x^6+3(a^2x^4)(bx)+3(ax^2)(bx)^2+(bx)^3$$
$$+3(ax^2+bx)^2c+3(ax^2+bx)c^2+c^3$$

Hence, if we are asked to find the cube root of the above expression we see that we have the following means of discovering successively the several terms of the root.

The first term of the root, *viz*, ax^2, is evidently the cube root of the first term of the given expression, which is a^3x^6

If we subtract a^3x^6 from the given expression the term containing the highest power of x in the remainder is $3(a^2x^4)(bx)$, *i e*, equal to three times the square of the first term of the root *into* the second term, the second term is therefore discovered

If from the above remainder we now subtract $\{3(a^2x^4)+3(ax^2)(bx)+(bx)^2\}(bx)$, the second remainder is $3(ax^2+bx)^2c+3(ax^2+bx)c^2+c^3$, the term containing the highest power of x in this remainder is $3a^2x^4c$, *i e*, equal to three times the square of the first term of the root *into* the third

Hence the third term is discovered

If from the second remainder we now subtract $\{3(ax^2+bx)^2+3(ax^2+bx)c+c^2\}c$, nothing is left and we obtain the required root $=ax^2+bx+c$

Let us illustrate the process by an example.

Example. Find the cube root of

$$x^6-6x^5y+24x^4y^2-56x^3y^3+96x^2y^4-96xy^5+64y^6$$

The given expression stands arranged according to descending powers of x, we need not therefore change the order of the terms

The second term of the root, *viz*, $-2xy$ as shewn on the next page, is obtained by dividing $-6x^5y$ by $3x^4$ (*i e*, three times the square of the first term)

Then the divisor, $3x^4-6x^3y+4x^2y^2$, is formed as shewn on the next page

The product of this divisor by $(-2xy)$, *viz*, $-6x^5y+12x^4y^2-8x^3y^3$, is now subtracted from the expression which stands above it and the remainder is put down below the line

Now take three times the square of the part of the root already obtained and put down the result, $3x^4-12x^3y+12x^2y^2$, as part of a divisor

The third term of the root, *viz*, $4y^2$, is obtained by dividing $12x^4y^2$, the first term of the remainder, by $3x^4$ the first term of the divisor

The complete divisor is then formed as shewn on the next page, and the product of this divisor by the third term of the root is subtracted from the expression which stands above it

As no remainder is now left we find the required root $=x^2-2xy+4y^2$.

$$x^6-6x^5y+24x^4y^2-56x^3y^3+96x^2y^4-96xy^5+64y^6\,(x^2-2xy+4y^2$$

$$x^6$$

$$-6x^5y+24x^4y^2-56x^3y^3+96x^2y^4-96xy^5+64y^6$$

$$3\times(x^2)^2=3x^4$$

$$3\times x^2\times(-2xy)=\quad -6x^3y$$

$$(-2xy)^2=\quad +4x^2y^2$$

$$3x^4-6x^3y+4x^2y^2 \quad\Big|\quad -6x^5y+12x^4y^2-8x^3y^3$$

$$12x^4y^2-48x^3y^3+96x^2y^4-96xy^5+64y^6$$

$$3\times(x^2-2xy)^2=3x^4-12x^3y+12x^2y^2$$

$$3\times(x^2-2xy)\times(4y^2)=\quad +12x^2y^2-24xy^3$$

$$(4y^2)^2=\quad +16y^4$$

$$3x^4-12x^3y+24x^2y^2-24xy^3+16y^4 \quad\Big|\quad 12x^4y^2-48x^3y^3+96x^2y^4-96xy^5+64y^6$$

EXERCISE 116.

Find the cube root of·

1. $x^3+27x^2+243x+729$
2. $27x^3-216x^2+576x-512$.
3. $64a^3-144a^2b+108ab^2-27b^3$.
4. $33x^4-36x+x^6-63x^3+8-9x^5+66x^2$
5. $8x^6+12x^5-30x^4-35x^3+45x^2+27x-27$
6. $1-9x^2+33x^4-63x^6+66x^8-36x^{10}+8x^{12}$
7. $c^6-63c^3x^3+8x^6-9c^5x+66c^2x^4-36cx^5+33c^4x^2$.

CHAPTER XXXII

RATIO AND PROPORTION

211. Definitions. The ratio of one quantity to another of the same kind is defined to be the **abstract number** (integral or fractional) which expresses what multiple, part or parts, the former is of the latter Thus,

since 2 hours is a portion of time which is three times as large as 40 minutes, the ratio of 2 hours to 40 minutes $=3$

since a length of 9 inches is a fourth part of 3 feet, the ratio of 9 inches to 3 feet $=\frac{1}{4}$

since the sum of £1 4*s* is obtained by dividing 18*s* into 3 equal parts and taking 4 of those parts, the ratio of £1 4*s* to 18*s* $=\frac{4}{3}$;

and so on

Hence, it is clear that the ratio of one *concrete* quantity to another (of the same kind) is a fraction, of which the numerator and denominator are respectively the *measures* of those quantities (*referred to one and the same unit*), and the ratio of one *abstract* quantity to another is a fraction of which the numerator and denominator are respectively the quantities themselves.

The ratio of any number a to any other number b is usually expressed by the notation $a : b$; thus $a : b$ is the same as $\frac{a}{b}$. The quantities a and b are respectively called the **antecedent** and the **consequent** (or the *first term* and the *second term*) of the ratio $a : b$.

A ratio is called a ratio of *greater inequality*, of *less inequality* or of *equality*, according as it is *greater* than, *less* than or *equal* to 1.

Note: *Since a ratio is only a fraction, there is no difficulty in seeing that the value of a ratio remains unaltered if its terms be multiplied or divided by the same number. Thus the ratios 3 : 4, 6 : 8, 15 : 20 and 3n : 4n are equal to one another. Hence also two or more ratios can be easily compared with one another; for instance, the ratios 2 : 3, 4 : 5 and 7 : 10 being respectively equivalent to 20 : 30, 24 : 30 and 21 : 30, we see at once that the second of them is the greatest and the first the least.*

212. A ratio of less inequality is increased and a ratio of greater inequality is diminished, by adding the same number to both its terms.

Let $\frac{a}{b}$ be any given ratio, and let $\frac{a+x}{b+x}$ be the new ratio formed by adding x to both its terms.

Then, $$\frac{a+x}{b+x}-\frac{a}{b}=\frac{x(b-a)}{b(b+x)},$$

and therefore it is positive or negative according as a is less or greater than b.

Hence, if $a<b$, $\frac{a+x}{b+x}>\frac{a}{b}$,

and if $a>b$, $\frac{a+x}{b+x}<\frac{a}{b}$;

which proves the proposition.

Note: *Similarly it can be proved that a ratio of less inequality is diminished, and a ratio of greater inequality is increased by subtracting from both its terms any number which is less than each of those terms. This is left as an exercise for the student.*

213. Composition of Ratios. The ratio of the product of the antecedents of any number of ratios to the product of their consequents is called the ratio **compounded** of the given ratios

Thus, the ratio compounded of the three ratios

$$3:4, \qquad 8:9, \qquad 2x:3y$$

is $\qquad 3\times8\times2x : 4\times9\times3y$

or, $\qquad 4x:9y$

When the ratio $a:b$ is compounded with itself the resulting ratio $a^2:b^2$ is called the **duplicate** ratio of $a:b$ Similarly, $a^3:b^3$ is called the **triplicate** ratio of $a:b$, $a^{\frac{1}{2}}:b^{\frac{1}{2}}$ is called the **sub-duplicate** ratio of $a:b$; and $a^{\frac{1}{3}}:b^{\frac{1}{3}}$ is called the **sub-triplicate** ratio of $a:b$

214. Approximate values of Ratios. If x is *very small* compared with a, to show that the ratio $(a+x)^2:a^2$ is approximately the same as $a+2x:a$

We have $\dfrac{(a+x)^2}{a^2}=\dfrac{a^2+2ax+x^2}{a^2}=1+\dfrac{2x}{a}+\dfrac{x^2}{a^2}$

and $\therefore$ *approximately* $=1+\dfrac{2x}{a}$,

since $\dfrac{x^2}{a^2}$ $\left(\text{which }=\dfrac{x}{a}\times\dfrac{x}{a}\right)$ is very small compared with $\dfrac{2x}{a}$ and smaller still than 1

Thus approximately we have

$$\frac{(a+x)^2}{a^2}=1+\frac{2x}{a}=\frac{a+2x}{a}. \qquad \text{.. (1)}$$

Cor. From (1), we have $\sqrt{\dfrac{a+2x}{a}}=\dfrac{a+x}{a}$. Hence, if x is very small compared with a, we have

$$\sqrt{a+x}:\sqrt{a}=a+\tfrac{1}{2}x:a$$

Note *By a similar mode of reasoning it can be shewn that when x is very small compared with a, $(a+x)^3:a^3=a+3x:a$, $(a+x)^4:a^4=a+4x:a$, $(a+x)^{\frac{1}{3}}:a^{\frac{1}{3}}=a+\frac{1}{3}x:a$, and so on*

215. Incommensurable Quantities. If two quantities be such that their ratio cannot be exactly expressed by the ratio of two integers, they are said to be

incommensurable quantities. Thus $\sqrt{3}$ and 2 are incommensurable quantities, since no two integers can be found whose ratio is *exactly* equal to $\sqrt{3}$ 2

Although the ratio of two incommensurable quantities cannot be *exactly* expressed by the ratio of two integers, we can always find two integers however, whose ratio differs from such a ratio by as small a quantity as we please

For instance, $\frac{\sqrt{3}}{2}=\frac{1\ 73205\ \cdot}{2}= 86602\ldots$

and therefore $\frac{\sqrt{3}}{2}>\frac{86602}{100000}$ and $<\frac{86603}{100000}$;

thus, $\sqrt{3}$ 2 differs from either 86602 100000 or 86603: 100000 by even less than a hundred-thousandth part of unity A further approximation might evidently be arrived at by calculating the value of $\sqrt{3}$ to more places of decimals

Note *Any number which cannot be* ***exactly*** *expressed as the ratio of two whole numbers is also sometimes called incommensurable. From this point of view every surd is an incommensurable quantity*

Examples

Example 1. Two numbers are in the ratio of 2 to 3, and 9 be added to each they are in the ratio of 3 to 4 Find the numbers

Since the numbers are in the ratio of 2 to 3, evidently we can represent them by $2x$ and $3x$ respectively.

Hence, by the second condition, we have

$$\frac{2x+9}{3x+9}=\frac{3}{4}.$$

Hence, $8x+36=9x+27$, whence $x=9$.

Therefore the numbers are 18 and 27.

Example 2. What is the ratio of x to y, if

$$10x+3y\ \ 5x+2y=9\ \ 5?$$

We have $$\frac{9}{5}=\frac{10x+3y}{5x+2y}=\frac{10\frac{x}{y}+3}{5\frac{x}{y}+2}.$$

Hence. $$45\frac{x}{y}+18=50\frac{x}{y}+15;$$

$$\therefore\quad 5\frac{x}{y}=3,\quad \therefore\ \frac{x}{y}=\frac{3}{5}.$$

Example 3. What is the greater (x and y being positive)

$$x^3+y^3\ \ x^2+y^2,\ \text{or,}\ x^2+y^2\ \ x+y\ ?$$

We have $$\frac{x^3+y^3}{x^2+y^2}-\frac{x^2+y^2}{x+y}=\frac{xy^3+x^3y-2x^2y^2}{(x^2+y^2)(x+y)}$$
$$=\frac{xy(x-y)^2}{(x^2+y^2)(x+y)},$$

which evidently is a positive quantity, since $(x-y)^2$ is positive whether x is greater or less than y

Hence, $x^3+y^3\ \ x^2+y^2 > x^2+y^2\ \ x+y$

Example 4. Two armies number 11000 and 7000 men respectively, before they fight, each is reinforced by 1000 men, in favour of which army is the increase ?

[C U Entr Paper, 1879]

The new strength of the 1st army its original strength

$$=12000\ \ 11000=12\ \ 11,$$

whilst, the new strength of the 2nd army its original strength

$$=8000\ \ 7000=8\cdot 7$$

Now since $12\ \ 11=84\ \ 77,$

and $8\cdot 7=88\ \ 77,$

it is clear that $8\ \ 7>12\ \ 11$

Thus, *compared* with the original strength, the new strength of the second army is greater than that of the first

Hence, the increase is in favour of the second army

EXERCISE 117.

Which is the greater

1. 4 5 or 7 8 ?　　**2.** 7.10 or 11 14 ?

3. 9 5 or 13 8 ?　　**4.** 22.27 or 32 45 ?

5. 28 · 39 or 49 65 ?

Find the ratio compounded of ·

6. $a\ \ b, b\ \ c$ and $c\ \ d$　　**7.** 3 5, 7 9 and 15 28

8. $a+x \quad a-x$, $a^2+x^2 : (a+x)^2$ and $(a^2-x^2)^2 \cdot a^4-x^4$

9. 16 5, the triplicate ratio of 5 4 and the sub-duplicate ratio of 9 . 4

10. 25 : 18, the sub-duplicate ratio of 81 49, the triplicate ratio of 2 . 3 and the duplicate ratio of 7 5.

11. If $2x+5y \quad 3x+5y=9 \quad 10$, find $x \quad y$

12. If $x \cdot y=3 \cdot 4$, find the value of $5x+9y \quad 16x+5y$

13. Two numbers are in the ratio of 7 · 8, and their sum is 135 Find the numbers

14. Find two numbers which are in the ratio of 5 3 and whose difference is 34

15. Two numbers are in the ratio of 4 5, and if 7 be added to each, the sums are in the ratio of 5 6 Find the numbers

16. Two numbers are in the ratio of 7 9, and if 10 be subtracted from each, the remainders are in the ratio of 8 11 Find the numbers

17. For what value of x will the ratio $23+x \quad 19+x$ be equal to 2 ?

18. What number must be added to each term of the ratio 25 37 that it may become equal to 5 6 ?

19. What number must be added to each term of the ratio 29 38 that it may become equal to 4 7 ?

20. What quantity must be added to each of the terms of the ratio $a \quad b$, that it may become equal to $c \quad d$?

21. Show that if $a > x$, the ratio $a^2-x^2 \quad a^2+x^2$ is greater than the ratio $a-x \,.\, a+x$

22. Show that the ratio $a^2+b^2 \cdot a+b$ is less than the ratio $a^2-b^2 \quad a-b$

Find approximately the values of

23. $(226)^3 \,.\, (225)^3$ **24.** $\sqrt{(3546)} \,.\, \sqrt{(3542)}$

25. A, B, C are three school boys getting monthly allowances of Rs 15, Rs 20 and Rs 25 respectively, out of these amounts they respectively spend Rs $8\frac{3}{4}$, Rs $11\frac{1}{4}$ and Rs $15\frac{5}{8}$ per month Which of them is the most frugal ?

PROPORTION

216. Definitions. Four quantities are said to be *proportionals* when the ratio of the first to the second is equal to the ratio of the third to the fourth Thus a, b, c, d are proportionals if $a : b = c : d$ This is often expressed as $a : b :: c : d$ and is read "a is to b as c is to d"

The terms a and d are called the **extremes** and the terms b and c, the **means.** The term d is also called the **fourth proportional** to a, b, c

Three or more quantities are said to be in continued proportion when the first is to the second as the second is to the third, as the third is to the fourth, and so on Thus a, b, c, d are in continued proportion when $a : b = b : c = c : d$

If three quantities a, b, c are in continued proportion ($a : b :: b : c$), then b is called the **mean proportional** between a and c, and c is called the **third proportional** to a and b

217. If $a : b :: c : d$, then will $ad = bc$.

Since $$\frac{a}{b} = \frac{c}{d},$$

multiplying both sides by bd, we have $ad = bc$.

Thus, *if four quantities are proportionals, the product of the extremes is equal to the product of the means*

[Conversely, if $ad = bc$, then $a : b :: c : d$ This is obvious by dividing both sides of the equality by bd]

Cor. If $a : b :: b : c$, then $ac = b^2$, *i e*, *if three quantities are in continued proportion, the product of the extremes is equal to the square of the mean*

Note *From the result above established we can at once find a third proportional to, or a mean proportional between two given quantities as well as a fourth proportional to three given quantities*

EXERCISE 118.

Find a third proportional to

1. 9, 6 **2.** 8, 12 **3.** 6, 15 **4.** 16, 24.

Find a fourth proportional to

5. 6, 8, 15. **6.** 14, 24, 35 **7.** ·0014, 1·4, ·02

Find a mean proportional between :

8. 4, 9. **9.** 7, 28 **10.** 6, 54.

218. If $a : b :: b : c$, then $a : c :: a^2 : b^2$.

For, $$\frac{a}{b} = \frac{b}{c};$$

$$\frac{a}{b} \times \frac{b}{c} = \frac{a}{b} \times \frac{a}{b};$$

or, $$\frac{a}{c} = \frac{a^2}{b^2}.$$

Thus, *if three quantities are in continued proportion, the first is to the third in the duplicate ratio of the first is to the second*

Note *Similarly, if $a : b = b : c = c : d$, it can be easily proved that $a : d = a^3 : b^3$, which is left as an exercise for the student*

219. If $a : b :: c : d$, then $b : a :: d : c$.

For, $$\frac{a}{b} = \frac{c}{d},$$

$$\therefore \quad 1 - \frac{a}{b} = 1 - \frac{c}{d}, \qquad \text{whence} \quad \frac{b}{a} = \frac{d}{c}.$$

Thus, *if four quantities be proportionals, they are also proportionals when taken inversely*

This operation is called **Invertendo.**

220. If $a : b :: c : d$, then $a : c :: b : d$.

For, $$\frac{a}{b} = \frac{c}{d};$$

$$\therefore \quad \frac{a}{b} \times \frac{b}{c} = \frac{c}{d} \times \frac{b}{c}, \qquad \text{or,} \quad \frac{a}{c} = \frac{b}{d}.$$

Thus, *if four quantities be proportionals, they are proportionals when taken alternately.*

This operation is called **Alternando.**

221. If $a : b :: c : d$, then $a+b : b :: c+d : d$.

For, $\dfrac{a}{b}=\dfrac{c}{d}$;

$\therefore \quad \dfrac{a}{b}+1=\dfrac{c}{d}+1, \qquad$ or, $\quad \dfrac{a+b}{b}=\dfrac{c+d}{d}$.

Thus, *when four quantities are proportionals, the first together with the second is to the second as the third together with the fourth is to the fourth.*

This operation is called **Componendo.**

222. If $a : b :: c : d$, then $a-b : b :: c-d : d$.

For, $\dfrac{a}{b}=\dfrac{c}{d}$;

$\therefore \quad \dfrac{a}{b}-1=\dfrac{c}{d}-1, \qquad$ or, $\quad \dfrac{a-b}{b}=\dfrac{c-d}{d}$.

Thus, *when four quantities are proportionals, the excess of the first over the second is to the second as the excess of the third over the fourth is to the fourth.*

This operation is called **Dividendo.**

***Cor.* If $a : b :: c : d$, then $a : a-b :: c : c-d$.**

For $\dfrac{a-b}{b}=\dfrac{c-d}{d}$; $\qquad$ inversely, $\dfrac{b}{a-b}=\dfrac{d}{c-d}$.

Hence, $\dfrac{b}{a-b}\times\dfrac{a}{b}=\dfrac{d}{c-d}\times\dfrac{c}{d}$, $\qquad$ or, $\quad \dfrac{a}{a-b}=\dfrac{c}{c-d}$.

Thus, *when four quantities are proportionals, the first is to the excess of the first over the second as the third is to the excess of the third over the fourth.*

This operation is called **Convertendo.**

223. If $a : b :: c : d$, then $a+b : a-b :: c+d : c-d$.

From Art 221, $\dfrac{a+b}{b}=\dfrac{c+d}{c}$. .. (1)

From Art 222, $\dfrac{a-b}{b}=\dfrac{c-d}{d}$. ... .. (2)

Hence, dividing (1) by (2),

$$\frac{a+b}{a-b}=\frac{c+d}{c-d}.$$

Thus, *when four quantities are proportionals, the sum of the first and second is to their difference as the sum of the third and fourth is to their difference*

This result is often spoken of as **Componendo and Dividendo.**

Note *The result proved in this article is of great use in solving a certain class of equations This will be illustrated in some of the following examples*

Example 1. Solve $\dfrac{\sqrt{a+x}+\sqrt{a-x}}{\sqrt{a+x}-\sqrt{a-x}}=b$

By componendo and dividendo, we have

$$\frac{2\sqrt{a+x}}{2\sqrt{a-x}}=\frac{b+1}{b-1}.$$

Hence, $$\frac{a+x}{a-x}=\left(\frac{b+1}{b-1}\right)^2=\frac{b^2+2b+1}{b^2-2b+1}.$$

Again applying componendo and dividendo,

$$\frac{2a}{2x}=\frac{2(b^2+1)}{4b}, \quad \text{or,} \quad \frac{a}{x}=\frac{b^2+1}{2b};$$

$$x(b^2+1)=2ab, \quad \therefore \quad x=\frac{2ab}{b^2+1}.$$

Example 2. Solve $\dfrac{1-ax}{1+ax}\sqrt{\dfrac{1+bx}{1-bx}}=1.$

We have $$\sqrt{\frac{1+bx}{1-bx}}=\frac{1+ax}{1-ax};$$

$$\frac{1+bx}{1-bx}=\frac{1+2ax+a^2x^2}{1-2ax+a^2x^2}.$$

Hence, by componendo and dividendo,

$$\frac{1}{bx}=\frac{1+a^2x^2}{2ax};$$

$$b(1+a^2x^2)=2a, \quad \text{or,} \quad a^2x^2=\frac{2a}{b}-1;$$

$$x=\frac{1}{a}\sqrt{\frac{2a}{b}-1}$$

Example 3. Find the value of $\dfrac{x+2a}{x-2a}+\dfrac{x+2b}{x-2b}$, when $x=\dfrac{4ab}{a+b}$. [Allahabad University Entrance Paper, 1892.]

From the given relation, we have

$$\frac{x}{2a}=\frac{2b}{a+b}, \text{ and } \frac{x}{2b}=\frac{2a}{a+b}.$$

Hence, by componendo and dividendo,

$$\frac{x+2a}{x-2a}=\frac{a+3b}{b-a}, \text{ and } \frac{x+2b}{x-2b}=\frac{3a+b}{a-b}.$$

Hence, the given expression

$$=\frac{-(a+3b)}{a-b}+\frac{3a+b}{a-b}$$

$$=\frac{2(a-b)}{a-b}=2.$$

Note. *For a different solution of this example see Art 171, Ex 2.*

Example 4. If $(a+b+c+d)(a-b-c+d)$
$=(a-b+c-d)(a+b-c-d)$, show that $a : b :: c : d$.

From the given relation, we have

$$\frac{a+b+c+d}{a+b-c-d}=\frac{a-b+c-d}{a-b-c+d}.$$

Hence, by componendo and dividendo,

$$\frac{a+b}{c+d}=\frac{a-b}{c-d};$$

$$\therefore \quad \frac{a+b}{a-b}=\frac{c+d}{c-d} \quad \text{[Alternando]},$$

whence by a second application of componendo and dividendo,

$$\frac{a}{b}=\frac{c}{d}.$$

Example 5. If $x=\dfrac{\sqrt[3]{m+1}+\sqrt[3]{m-1}}{\sqrt[3]{m+1}-\sqrt[3]{m-1}}$, show that

$$x^3-3mx^2+3x-m=0.$$

From the given relation, by componendo and dividendo, we have

$$\frac{x+1}{x-1}=\frac{\sqrt[3]{m+1}}{\sqrt[3]{m-1}};$$

$$\frac{m+1}{m-1}=\frac{(x+1)^3}{(x-1)^3}=\frac{x^3+3x^2+3x+1}{x^3-3x^2+3x-1}.$$

Hence, by a second application of componendo and dividendo, we have

$$\frac{m}{1}=\frac{x^3+3x}{3x^2+1};$$

$$m(3x^2+1)=x^3+3x.$$

whence, $x^3-3mx^2+3x-m=0$.

EXERCISE 119.

Solve the following equations

1. $\left.\begin{aligned}\frac{x+y}{x-y}&=5\\ 2x+3y&=36\end{aligned}\right\}$

2. $\left.\begin{aligned}\frac{3x-5y}{3x+5y}&=\frac{1}{4}\\ 4x-9y&=19\end{aligned}\right\}$

3. $\left.\begin{aligned}\frac{5x-7y}{5x+7y}&=\frac{1}{7}\\ 3x-5y&=18\end{aligned}\right\}$

4. $16\left(\frac{a-x}{a+x}\right)^3=\frac{a+x}{a-x}$. [C U Entr. Paper, 1886]

5. $\frac{2x+\sqrt{4x^2-1}}{2x-\sqrt{4x^2-1}}=4$

6. $\frac{1-\sqrt{1-x}}{1+\sqrt{1-x}}=\frac{1}{3}$.

7. $\frac{\sqrt{36x+1}+\sqrt{36x}}{\sqrt{36x+1}-\sqrt{36x}}=9$

8. $\frac{1+x+x^2}{1-x+x^2}=\frac{62}{63}\cdot\frac{1+x}{1-x}$.

9. $\frac{\sqrt{5}+\sqrt{5-x}}{\sqrt{5}-\sqrt{5-x}}=5$

10. $\frac{a+x+\sqrt{a^2-x^2}}{a+x-\sqrt{a^2-x^2}}=\frac{b}{x}$.

11. $\frac{a^{\frac{1}{2}}-\{a-(a^2-ax)^{\frac{1}{2}}\}^{\frac{1}{2}}}{a^{\frac{1}{2}}+\{a-(a^2-ax)^{\frac{1}{2}}\}^{\frac{1}{2}}}=b$

Prove that $a : b :: c : d$—

12. If $(a+3b+2c+6d)(a-3b-2c+6d)$
$=(a-3b+2c-6d)(a+3b-2c-6d)$.

13. If $(2a+b+4c+2d)(2a-b-4c+2d)$
$=(2a-b+4c-2d)(2a+b-4c-2d)$.

14. If $x=\frac{\sqrt{2a+3b}+\sqrt{2a-3b}}{\sqrt{2a+3b}-\sqrt{2a-3b}}$, show that
$$3bx^2-4ax+3b=0$$

15. If $x=\dfrac{2\sqrt{24}}{\sqrt{2}+\sqrt{3}}$, find the value of $\dfrac{x+\sqrt{8}}{x-\sqrt{8}}+\dfrac{x+\sqrt{12}}{x-\sqrt{12}}$.

224. An Important Theorem. If $\dfrac{a}{b}=\dfrac{c}{d}=\dfrac{e}{f}$, then each of these ratios $=\left(\dfrac{pa^n+qc^n+re^n}{pb^n+qd^n+rf^n}\right)^{\frac{1}{n}}$, where p, q, r, n are any quantities whatever

Supposing each of the given ratios $=k$, we have $a=bk$, $c=dk$, $e=fk$

Hence, $\left.\begin{aligned} pa^n&=p(bk)^n=pb^n k^n \\ qc^n&=q(dk)^n=qd^n k^n \\ re^n&=r(fk)^n=rf^n k^n \end{aligned}\right\}$ $\quad \begin{aligned} &pa^n+qc^n+re^n \\ &\quad=(pb^n+qd^n+rf^n)k^n, \end{aligned}$

whence, $\quad k^n=\dfrac{pa^n+qc^n+re^n}{pb^n+qd^n+rf^n}$;

and $\quad k=\left(\dfrac{pa^n+qc^n+re^n}{pb^n+qd^n+rf^n}\right)^{\frac{1}{n}}$, which proves the proposition

Cor. As a particular case, if q, q, r, n be each equal to 1, we have each of the given ratios $=\dfrac{a+c+e}{b+d+f}$.

Similarly, giving different sets of values to p, q, r, n several particular cases may be at once deduced.

Note *What is proved above for* ***three*** *equal ratios is obviously true for* ***any number*** *of equal ratios, the same reasoning being applicable to all cases It is always a very good exercise for the student however to work out independently every fresh example of this class applying the mode of demonstration illustrated above Hence an exercise is added below with a recommendation to the student that he should find the result in* ***each*** *case* ***without using the formula*** *established in this article*

EXERCISE 120.

If $\dfrac{a}{b}=\dfrac{c}{d}=\dfrac{e}{f}$, prove that each of these ratios is equal to

1. $\dfrac{a-c+e}{b-d+f}$. **2.** $\dfrac{a+3c-5e}{b+3d-5f}$. **3.** $\dfrac{5a-7c-13e}{5b-7d-13f}$.

4. $\dfrac{ka+lc+me}{kb+ld+mf}$. 5. $\left(\dfrac{a^2+c^2+e^2}{b^2+d^2+f^2}\right)^{\frac{1}{2}}$. 6. $\left(\dfrac{a^3-2c^3+3e^3}{b^3-2d^3+3f^3}\right)^{\frac{1}{3}}$.
[C U 1875]

7. $\dfrac{\sqrt[3]{a^3+c^3+e^3}}{\sqrt[3]{b^3+d^3+f^3}}$. [C U Entr Paper, 1882]

If $\dfrac{a}{b}=\dfrac{c}{d}=\dfrac{e}{f}=\dfrac{g}{h}$, prove that each of these ratios is equal to

8. $\left(\dfrac{a^{-1}+c^{-1}+e^{-1}+g^{-1}}{b^{-1}+d^{-1}+f^{-1}+h^{-1}}\right)^{-1}$. 9. $\sqrt[4]{\dfrac{a^4-2c^4+3e^4-4g^4}{b^4-2d^4+3f^4-4h^4}}$.

10. $\sqrt{\left(\dfrac{3a^{-2}-7c^{-2}-8e^{-2}+15g^{-2}}{3b^{-2}-7d^{-2}-8f^{-2}+15h^{-2}}\right)^{-1}}$.

225. Miscellaneous Examples.

Example 1. If $x \cdot y \cdot\ m^2\ \ n^2$, and
$m\ \ n\ \ \sqrt{p^2+x^2}\ \ \sqrt{p^2-y^2}$, then $p^2\ \ xy\ \ x+y\ \ x-y$.

We have $\dfrac{x}{y}=\dfrac{m^2}{n^2}=\dfrac{p^2+x^2}{p^2-y^2}$;

. $x(p^2-y^2)=y(p^2+x^2)$, [Art 217]

or, $p^2(x-y)=xy(x+y)$,

$\dfrac{p^2}{xy}=\dfrac{x+y}{x-y}$; [Art 217, Converse]

i e $p^2\ \ xy\ \ x+y\ \ x-y$

Example 2. If $a\ \ b\ \ c\ .\ d$, show that

$$ma+nc\ \ mb+nd\ \ (a^2+c^2)^{\frac{1}{2}}\ \ (b^2+d^2)^{\frac{1}{2}}.$$

[C U Entr Paper, 1880

Since $\dfrac{a}{b}=\dfrac{c}{d}$; . $\dfrac{ma}{mb}=\dfrac{nc}{nd}$,

and therefore each of them $=\dfrac{ma+nc}{mb+nd}$. [Art 224]

Again, since $\dfrac{a}{b}=\dfrac{c}{d}$; $\dfrac{a^2}{b^2}=\dfrac{c^2}{d^2}$,

and therefore each of them $=\dfrac{a^2+c^2}{b^2+d^2}$. [Art. 224]

Thus we have $\frac{ma+nc}{mb+nd}=\frac{ma}{mb}=\frac{a}{b}$, (1)

and $\frac{a^2+c^2}{b^2+d^2}=\frac{a^2}{b^2}$. . (2)

Hence from (1) and (2),

$$\frac{ma+nc}{mb+nd}=\frac{(a^2+c^2)^{\frac{1}{2}}}{(b^2+d^2)^{\frac{1}{2}}},$$ which was to be proved

Example 3. If $\frac{x}{(b-c)(b+c-2a)}=\frac{y}{(c-a)(c+a-2b)}$

$=\frac{z}{(a-b)(a+b-2c)}$, find the value of $x+y+z$

[C U Entr Paper, 1889]

Let each of the given ratios $=k$

Then, $x=k(b-c)(b+c-2a)=k\{(b^2-c^2)-2a(b-c)\}$,
$y=k(c-a)(c+a-2b)=k\{(c^2-a^2)-2b(c-a)\}$,
$z=k(a-b)(a+b-2c)=k\{(a^2-b^2)-2c(a-b)\}$

Hence, $x+y+z$

$$=k[\{(b^2-c^2)+(c^2-a^2)+(a^2-b^2)\} \\ -2\{a(b-c)+b(c-a)+c(a-b)\}]$$

$=0$

Example 4. If $\frac{ay-bx}{c}=\frac{cx-az}{b}=\frac{bz-cy}{a}$,

show that $\frac{x}{a}=\frac{y}{b}=\frac{z}{c}$.

Let each of the given ratios $=k$

Then, we have $(ay-bx)c=kc^2$,
$(cx-az)b=kb^2$,
$(bz-cy)a=ka^2$

Hence, by addition,

$$k(a^2+b^2+c^2)=0,$$
$$k=0$$

Hence, $ay-bx=0$, $\therefore$ $ay=bx$, $\therefore$ $\frac{x}{a}=\frac{y}{b}$ (1)

also, $cx-az=0$, $\therefore$ $cx=az$, $\frac{x}{a}=\frac{z}{c}$. . (2)

Hence, from (1) and (2), $\frac{x}{a}=\frac{y}{b}=\frac{z}{c}$.

Example 5. If $\frac{a}{b}=\frac{b}{c}=\frac{c}{d}$, then will

$$(a-d)^2=(b-c)^2+(c-a)^2+(d-b)^2$$

From the given relations, we have

(i) $b^2=ac$, (ii) $c^2=bd$; (iii) $bc=ad$ [Art 217]

Now, $(b-c)^2+(c-a)^2+(d-b)^2$

$$=(b^2+c^2-2bc)+(c^2+a^2-2ac)+(d^2+b^2-2bd)$$
$$=2(b^2-ac)+2(c^2-bd)+a^2+d^2-2bc$$
$$=a^2+d^2-2bc \qquad \text{[from (i) and (ii)]}$$
$$=a^2+d^2-2ad \qquad \text{[from (iii).]}$$
$$=(a-d)^2$$

Example 6. If $a : b :: c : d$, show that

$$4(a+b)(c+d)=bd\left\{\frac{a+b}{b}+\frac{c+d}{d}\right\}^2.$$

[C. U Entr Paper, 1874]

Since $\frac{a}{b}=\frac{c}{d}$; $\therefore$ $\frac{a+b}{b}=\frac{c+d}{d}$; [componendo]

clearly therefore, $\frac{a+b}{b}+\frac{c+d}{d}=\frac{2(a+b)}{b}=\frac{2(c+d)}{d}$.

Hence, $$\left\{\frac{a+b}{b}+\frac{c+d}{d}\right\}^2=\frac{2(a+b)}{b}\times\frac{2(c+d)}{d}$$
$$=\frac{4(a+b)(c+d)}{bd};$$

$$bd\left\{\frac{a+b}{b}+\frac{c+d}{d}\right\}^2=4(a+b)(c+d).$$

Example 7. If $a : b :: p : q$, show that

$$a^2+b^2 : \frac{a^3}{a+b} :: p^2+q^2 : \frac{p^3}{p+q}.$$

From the given relations, we have

$$\frac{b}{a}=\frac{q}{p}, \quad \text{and} \quad \therefore \frac{b^2}{a^2}=\frac{q^2}{p^2}.$$

Hence, (i) $\frac{a+b}{a}=\frac{p+q}{q}$, and (ii) $\frac{a^2+b^2}{a^2}=\frac{p^2+q^2}{q^2}$.

Multiplying together (i) and (ii), we have

$$\frac{(a^2+b^2)(a+b)}{a^3}=\frac{(p^2+q^2)(p+q)}{p^3},$$

or, $$\frac{a^2+b^2}{\left(\dfrac{a^3}{a+b}\right)}=\frac{p^2+q^2}{\left(\dfrac{p^3}{p+q}\right)};$$

i e, $$a^2+b^2 : \frac{a^3}{a+b} :: p^2+q^2 : \frac{p^3}{p+q}.$$

Example 8. If $m : n :: p : q$, prove that

$$\frac{(m-n)(m-p)}{m}=(m+q)-(n+p)$$

[C U Entr Paper 1859]

We have $\dfrac{m}{n}=\dfrac{p}{q}$; $\qquad \therefore \dfrac{m-n}{n}=\dfrac{p-q}{q}$;

alternately, $\dfrac{m}{p}=\dfrac{n}{q}$; $\qquad \therefore \dfrac{m-p}{p}=\dfrac{n-q}{q}$.

Hence, $$\frac{(m-n)(m-p)}{np}=\frac{(p-q)(n-q)}{q^2}$$

or, $$\frac{(m-n)(m-p)}{mq}=\frac{(p-q)(n-q)}{q^2} \qquad [\because np=mq.]$$

$$\therefore \frac{(m-n)(m-p)}{m}=\frac{pn-q(n+p)+q^2}{q}$$

$$=\frac{mq+q^2-q(n+p)}{q} \qquad [\because pn=mq]$$

$$=(m+q)-(n+p)$$

Example 9. If $\dfrac{a}{b}=\dfrac{b}{c}=\dfrac{c}{d}$, show that

$$(a^2+b^2+c^2)(b^2+c^2+d^2)=(ab+bc+cd)^2$$

[C. U Entr Paper, 1887]

Let each of the given ratios $=k$

Then $\left.\begin{aligned} k^2b^2 &= a^2 \\ k^2c^2 &= b^2 \\ k^2d^2 &= c^2 \end{aligned}\right\}$ $\quad \therefore k^2(b^2+c^2+d^2)=a^2+b^2+c^2,$

$$\therefore k^2=\frac{a^2+b^2+c^2}{b^2+c^2+d^2}; \quad \ldots \quad \ldots \quad (1)$$

also, $\left.\begin{aligned} kb=a\,; &\quad kb^2=ab \\ kc=b\,, &\quad \therefore kc^2=bc \\ kd=c\,, &\quad \therefore kd^2=cd \end{aligned}\right\}$ $\quad \therefore k(b^2+c^2+d^2)=ab+bc+cd,$

$$\therefore k=\frac{ab+bc+cd}{b^2+c^2+d^2} \quad \ldots \quad \ldots \quad (2)$$

Hence equating the value of k^2 from (1) and (2), we have

$$\frac{a^2+b^2+c^2}{b^2+c^2+d^2}=\frac{(ab+bc+cd)^2}{(b^2+c^2+d^2)^2};$$

$$(a^2+b^2+c^2)(b^2+c^2+d^2)=(ab+bc+cd)^2$$

Example 10. If $\frac{a}{b}=\frac{c}{d}=\frac{e}{f}$, show that

$$\sqrt{(a+c+e)(b+d+f)}=(ab)^{\frac{1}{2}}+(cd)^{\frac{1}{2}}+(ef)^{\frac{1}{2}}.$$

Let each of the given ratios $=k$

Then $\left.\begin{aligned}a&=bk\\ c&=dk\\ e&=fk\end{aligned}\right\}$. $a+c+e=k(b+d+f)$,

$$(a+c+e)(b+d+f)=k(b+d+f)^2,$$

$$\sqrt{(a+c+e)(b+d+f)}=(b+d+f)\sqrt{k} \qquad (1)$$

Also, we have $ab=b^2k$, $\quad (ab)^{\frac{1}{2}}=b\sqrt{k}$

$cd=d^2k$, $\quad (cd)^{\frac{1}{2}}=d\sqrt{k}$

$ef=f^2k$, $\quad$ · $(ef)^{\frac{1}{2}}=f\sqrt{k}$

$$(ab)^{\frac{1}{2}}+(cd)^{\frac{1}{2}}+(ef)^{\frac{1}{2}}=(b+d+f)\sqrt{k} \qquad (2)$$

Hence, from (1) and (2),

$$\sqrt{(a+c+e)(b+d+f)}=(ab)^{\frac{1}{2}}+(cd)^{\frac{1}{2}}+(ef)^{\frac{1}{2}}$$

EXERCISE 121.

If a be the greatest of the four quantities a, b, c, d and if a b c d, show that·

1. b and c are each $> d$ **2.** $a-b > c-d$ **3.** $a+d > b+c$

If a b c · d, show that

4. $ma+nb$ b $mc+nd$ d

5. $ma+nb$ $mc+nd$ $pa-qb$ $pc-qd$

6. a b $a+c$ $b+d$ **7.** a^2 b^2 a^2+c^2 b^2+d^2.

8. a^2+c^2 b^2+d^2 ac bd. [C U Entı Papeı, 1877]

9. $(a-c)^2$ $(b-d)^2=a^2$ b^2

10. $(a+c)^3$ $(b+d)^3=a(a-c)^2$ $b(b-d)^2$

[C U Entı Paper, 1888]

11. $a^2+b^2 \quad a^2-b^2=ac+bd \quad ac-bd$

12. $a(a+c) \quad c^2 \quad b(b+d) \quad d^2$

13. $c \cdot d=\sqrt{a^2+c^2} \quad \sqrt{b^2+d^2}$

14. $a+b \,.\, c+d=\sqrt{a^2+b^2} \quad \sqrt{c^2+d^2}$

15. $a+b \quad c+d \quad \sqrt{3a^2+5b^2} \quad \sqrt{3c^2+5d^2}$

16. $a^2+ab+b^2 \quad a^2-ab+b^2 \quad c^2+cd+d^2 \quad c^2-cd+d^2$

17. $a^2+ac+c^2 \quad a^2-ac+c^2 \quad b^2+bd+d^2 \cdot b^2-bd+d^2$

If $a \quad b=c \quad d=e \quad f$, show that

18. $\dfrac{ma+nb}{mc+nd}=\dfrac{b^2c}{d^2a}$. [C U. Entr. Paper, 1876]

19. $ac \quad bd \quad 2a^2+3c^2+5e^2 \quad 2b^2+3d^2+5f^2$

20. $a^2+c^2+e^2 \quad b^2+d^2+f^2 \quad ce \quad df$ [C U Entr Paper, 1876]

21. $pa+qc+re \,.\, pb+qd+rf \quad \sqrt[3]{ace} : \sqrt[3]{bdf}$

22. $a^2 \quad b^2 \quad ac+ce+ae \quad bd+df+bf$

23. $a^3+c^3+e^3 \quad b^3+d^3+f^3 \quad ace \quad bdf$

24. $\sqrt{a^3c^3+c^3e^3+a^3e^3} \quad \sqrt{b^3d^3+d^3f^3+b^3f^3} \quad ace \,.\, bdf$

25. If a, b, c, d, e be in continued proportion, show that

$$a \quad e \,.\, a^4 \quad b^4.$$

26. If $\dfrac{x}{b+c-a}=\dfrac{y}{c+a-b}=\dfrac{z}{a+b-c}$, find the value of

$(b-c)x+(c-a)y+(a-b)z$ [C U Entr Paper, 1878]

27. If $a \quad b \cdot c \quad d$, prove that

$$a^2+c^2 \quad b^2+d^2 \quad \sqrt{a^4+c^4} \quad \sqrt{b^4+d^4}$$

28. If $a \quad b=c \cdot d=e \quad f$, show that

$$27(a+b)(c+d)(e+f)=bdf\left(\frac{a+b}{b}+\frac{c+d}{d}+\frac{e+f}{f}\right)^3$$

29. If $a \quad b \quad c \quad d$, show that $ad+bc \quad 2bd \quad a^2+c^2 \quad ab+cd$

30. If $a \quad b \,.\, c \quad d$, show that

$$a^2+b^2 \quad ab+ad-bc \,.\, c^2+d^2 \,.\, cd-ad+bc$$

If $a : b \quad b \quad c$, show that

31. $a^2+ab+b^2 \quad b^2+bc+c^2=a \quad c$

32. $a-2b+c=\dfrac{(a-b)^2}{a}=\dfrac{(b-c)^2}{c}$.

33. $a^2b^2c^2\left(\frac{1}{a^3}+\frac{1}{b^3}+\frac{1}{c^3}\right)=a^3+b^3+c^3.$

If $a:b=b:c=c:d$, show that

34. $(b+c)(b+d)=(c+a)(c+d)$

35. $(a+d)(b+c)-(a+c)(b+d)=(b-c)^2$

36. $\left(\frac{a-b}{c}+\frac{a-c}{b}\right)^2-\left(\frac{d-b}{c}+\frac{d-c}{b}\right)^2=(a-d)^2\left(\frac{1}{c^2}-\frac{1}{b^2}\right).$

37. $a:b=\frac{1}{b}+\frac{1}{c}+\frac{1}{d}:\frac{1}{a}+\frac{1}{b}+\frac{1}{c}.$

38. $a:d=a^3+b^3+c^3:b^3+c^3+d^3$

39. If $a:b::c:d$, show that

$$a^2+ab:c^2+cd::b^2-2ab:d^2-2cd$$

40. If $a:b=c:d=e:f$, show that

$$(a^2+b^2)(ce+df)^2=(c^2+d^2)(ae+bf)^2=(e^2+f^2)(ac+bd)^2.$$

CHAPTER XXXIII

ELIMINATION, MISCELLANEOUS THEOREMS AND ARTIFICES

I. Elimination.

226. If there be *two* equations involving *one* unknown quantity they will generally not be satisfied by the same value of it For instance the same value of x will *not* satisfy the equations $x+3=7$ and $x+4=9$ But this cannot be strictly said of the two equations $x+a=7$ and $x+b=9$, where a and b have no fixed numerical values, the appropriate remark in this case would be "the two equations *will be* satisfied by the same value of x *if* $7-a=9-b$, or, $b-a=2$" Thus if *one* unknown quantity occurs in *two* equations which *also* involve other *algebraical symbols*, there always exists a particular relation between these other symbols for which, and for which alone, *both* the given equations are satisfied by the *same* value of the unknown quantity The process of finding this relation is called the **Elimination** of the unknown quantity from the given equations, and the relation obtained is called the **Eliminant** of those equations.

Similarly there may be a question of eliminating two unknown quantities from three given equations For instance, the three equations $x+y=a$, $x+2y=b$, $x+3y=c$, *cannot* be *all* satisfied by the *same* values of x and y *unless* the quantities a, b, c are connected with one another in a certain way, and this connection may be necessary to investigate

A few simple cases of elimination will now be presented to the student, calculated to give him a tolerably clear idea of the subject, as also to familiarise him with some of the various ways of dealing with such questions

Example 1. Eliminate x from the equations

$$a_1x+b_1=0,\ a_2x+b_2=0$$

From the first equation, we have $x=-\frac{b_1}{a_1}$, and from the second equation $x=-\frac{b_2}{a_2}$.

Evidently therefore both the equations will be satisfied by the same value of x if $\frac{b_1}{a_1}=\frac{b_2}{a_2}$, or, $a_1b_2=a_2b_1$

Thus $a_1b_2=a_2b_1$ is the required eliminant.

Example 2. Eliminate x from the equations

$$a_1x^2+b_1x+c_1=0,\ a_2x^2+b_2x+c_2=0$$

Let α be the value of x which satisfies both the equatoins Then we must have

$$\left.\begin{array}{l} a_1\alpha^2+b_1\alpha+c_1=0 \\ a_2\alpha^2+b_2\alpha+c_2=0 \end{array}\right\}$$

Hence, by cross multiplication.

$$\frac{\alpha^2}{b_1c_2-b_2c_1}=\frac{\alpha}{c_1a_2-c_2a_1}=\frac{1}{a_1b_2-a_2b_1};$$

$$\therefore\quad \frac{\alpha^2}{b_1c_2-b_2c_1}\times\frac{1}{a_1b_2-a_2b_1}=\left(\frac{\alpha}{c_1a_2-c_2a_1}\right)^2,$$

whence, $(b_1c_2-b_2c_1)(a_1b_2-a_2b_1)=(c_1a_2-c_2a_1)^2$, which is the required eliminant

Example 3. Eliminate x and y from the equations

$$\left.\begin{array}{l} a_1x+b_1y+c_1=0 \\ a_2x+b_2y+c_2=0 \\ a_3x+b_3y+c_3=0 \end{array}\right\}$$

From the first two equations, by cross multiplication, we have

$$\frac{x}{b_1c_2-b_2c_1}=\frac{y}{c_1a_2-c_2a_1}=\frac{1}{a_1b_2-a_2b_1},$$

$$\therefore \quad x=\frac{b_1c_2-b_2c_1}{a_1b_2-a_2b_1}, \quad y=\frac{c_1a_2-c_2a_1}{a_1b_2-a_2b_1}.$$

If the third equation also be satisfied by these values of x and y, we must evidently have

$$a_3.\frac{b_1c_2-b_2c_1}{a_1b_2-a_2b_1}+b_3\frac{c_1a_2-c_2a_1}{a_1b_2-a_2b_1}+c_3=0,$$

or, $a_3(b_1c_2-b_2c_1)+b_3(c_1a_2-c_2a_1)+c_3(a_1b_2-a_2b_1)=0$, which is the required eliminant

Example 4. Eliminate x, y, z from the equations

$$\frac{ax}{by+cz}=\frac{by}{cz+ax}=\frac{z}{x+y}=\frac{1}{2}.$$

We have $$\frac{ax}{by+cz}=\frac{1}{2},$$

$$\therefore \quad 2ax=by+cz, \text{ or, } 2ax-by-cz=0. \qquad (1)$$

Also $$\frac{by}{cz+ax}=\frac{1}{2},$$

$$\therefore \quad 2by=cz+ax, \text{ or, } ax-2by+cz=0 \qquad (2)$$

Hence, from (1) and (2), by cross multiplication, we have

$$\frac{x}{-bc-2bc}=\frac{y}{-ca-2ca}=\frac{z}{-4ab+ab},$$

or, $$\frac{x}{-3bc}=\frac{y}{-3ca}=\frac{z}{-3ab},$$

or, $$\frac{x}{bc}=\frac{y}{ca}=\frac{z}{ab}.$$

Supposing each of these ratios $=k$, we have

$$x=k\,bc, \quad y=k\,ca, \quad z=k\,ab.$$

Substituting these values of x, y, z in the third equation which is $2z=x+y$, we have

$$2k\,ab=k(bc+ca),$$

or, $$2ab=bc+ac,$$

$$\therefore \quad \frac{2}{c}=\frac{1}{a}+\frac{1}{b},$$

which is the required eliminant

Note *It may be noticed in this example that the three given equations $2ax-by-cz=0$, $ax-2by+cz=0$ and $2z=x+y$ virtually involve* **two** *unknown quantities, instead of three, for they are respectively equivalent to* $2a\left(\frac{x}{z}\right)-b\left(\frac{y}{z}\right)-c=0$, $\left(\frac{x}{z}\right)-2b\left(\frac{y}{z}\right)+c=0$ *and* $2=\left(\frac{x}{z}\right)+\left(\frac{y}{z}\right)$, *in which the only unknown quantities are* $\frac{x}{z}$ *and* $\frac{y}{z}$.

It is owing to this disguised character (so to speak) of the three given equations that we have been able to eliminate from them the **three** *unknown quantities, x, y, z,* **otherwise** *a fourth equation would have been required for the purpose*

Example 5. Eliminate x from the equations

$$x^3+\frac{3}{x}=4(a^3+b^3),\quad 3x+\frac{1}{x^3}=4(a^3-b^3)$$

Adding together the equations, we have

$$x^3+3x+\frac{3}{x}+\frac{1}{x^3}=8a^3,$$

$$\text{or,}\quad \left(x+\frac{1}{x}\right)^3=(2a)^3,$$

$$x+\frac{1}{x}=2a \qquad (1)$$

Subtracting the second equation from the first, we have

$$x^3-3x+\frac{3}{x}-\frac{1}{x^3}=8b^3,$$

$$\text{or,}\quad \left(x-\frac{1}{x}\right)^3=(2b)^3,$$

$$\therefore\quad x-\frac{1}{x}=2b \quad .. \qquad (2)$$

From (1) and (2), by addition,

$$2x=2(a+b),\quad \text{or, } x=a+b,$$

and by subtraction, $\frac{2}{x}=2(a-b)$, or, $\frac{1}{x}=a-b$.

Hence, $(a+b)(a-b)=x\times\frac{1}{x}=1$

Thus $a^2-b^2=1$ is the required eliminant

Example 6. Eliminate x, y, z from the equations

$$\left.\begin{array}{lr} x+y+z=a & (1) \\ 2(yz+zx+xy)=b^2 & (2) \\ x^3+y^3+z^3=c^3 & (3) \\ 3xyz=d^3 & (4) \end{array}\right\}$$

Since, $x^2+y^2+z^2=(x+y+z)^2-2(yz+zx+xy)$,

. from (1) and (2), it $=a^2-b^2$ . . (5)

Now, since $x^3+y^3+z^3-3xyz$

$$=(x+y+z)(x^2+y^2+z^2-yz-zx-xy)$$
$$=(x+y+z)\{(x^2+y^2+z^2)-(yz+zx+xy)\}.$$

from (3), (4), (1), (5) and (2), we must have

$$c^3-d^3=a\{(a^2-b^2)-\tfrac{1}{2}b^2\}=a^3-\tfrac{3}{2}ab^2,$$
$$\text{or, } 2a^3-3ab^2-2c^3+2d^3=0,$$

which is the required eliminant

Example 7. Eliminate x, y, z from the equations

(i) $x^2(y+z)=a^2$, (ii) $y^2(x+z)=b^2$;

(iii) $z^2(x+y)=c^2$, (iv) $xyz=abc$

Multiplying the first three equations together, we have

$$x^2y^2z^2(y+z)(z+x)(x+y)=a^2b^2c^2$$

Hence, from (iv), $(y+z)(z+x)(x+y)=1$. . (α)

But $(y+z)(z+x)(x+y)=(y+z)\{x^2+x(y+z)+yz\}$

$$=x^2(y+z)+x(y^2+z^2+2yz)+yz(y+z)$$
$$=x^2(y+z)+y^2(x+z)+z^2(x+y)+2xyz,$$

and . from the given equations it $=a^2+b^2+c^2+2abc$

Hence, from (α), we have $a^2+b^2+c^2+2abc=1$, as the required eliminant

EXERCISE 122.

Eliminate x from the equations

1. $\left.\begin{array}{l} a^2x^2-b^2=0 \\ cx-d=0 \end{array}\right\}$ **2.** $\left.\begin{array}{l} ax^2-b=0 \\ cx^3-d=0 \end{array}\right\}$

3. $\left.\begin{array}{l} mx^3-n=0 \\ px^4-q=0 \end{array}\right\}$ **4.** $\left.\begin{array}{l} ax^2+bx+c=0 \\ x+d=0 \end{array}\right\}$

5. $\left.\begin{array}{l} lx^2+mx+n=0 \\ ax+b \qquad\quad =0 \end{array}\right\}$ **6.** $\left.\begin{array}{l} ax^2+bx+c=0 \\ lx^2+mx+n=0 \end{array}\right\}$

7. $\left.\begin{array}{l} x+\dfrac{1}{x}=a+b \\ x-\dfrac{1}{x}=a-b \end{array}\right\}$ **8.** $\left.\begin{array}{l} 2x+\dfrac{3}{x}=5p+7q \\ 2x-\dfrac{3}{x}=5p-7q \end{array}\right\}$

9. $\left.\begin{array}{l} a_1x^3+b_1x \;+c_1=0 \\ a_2x^3+b_2x \;+c_2=0 \end{array}\right\}$ **10.** $\left.\begin{array}{l} a_1x^3+b_1x^2+c_1=0 \\ a_2x^3+b_2x^2+c_2=0 \end{array}\right\}$

11. $\left.\begin{array}{l} a_1x^4+b_1x^3+c_1=0 \\ a_2x^4+b_2x^3+c_2=0 \end{array}\right\}$ **12.** $\left.\begin{array}{ll} ax^3+bx+c=0 & (1) \\ x^2+mx+n=0 & (2) \end{array}\right\}$

[Multiply (2) by ax and subtract (1) from the resulting equation, we thus get $amx^2+(an-q)x-c=0$ Now eliminate x from this equation and (2)]

13. $\left.\begin{array}{l} ax^2+bx+c=0 \\ x^3+2x^2+3=0 \end{array}\right\}$

Eliminate x and y from the equations

14. $\left.\begin{array}{l} ax+by=m \\ bx-ay=n \\ x^2+y^2=1 \end{array}\right\}$ **15.** $\left.\begin{array}{l} ax+b \;=\; cy \\ a_1y+b_1=c_1x \\ x^2+y^2 \;=\; 1 \end{array}\right\}$

16. $\left.\begin{array}{l} ax+by \qquad\quad =0 \\ lx^2+mxy+ny^2=0 \end{array}\right\}$

Eliminate x, y, z from the equations ·

17. $\dfrac{x}{y+z}=a,\ \dfrac{y}{z+x}=b,\ \dfrac{z}{x+y}=c$

18. $\dfrac{y-z}{y+z}=a,\ \dfrac{z-x}{z+x}=b,\ \dfrac{x-y}{x+y}=c$

19. $\dfrac{y}{z}+\dfrac{z}{y}=a,\ \dfrac{z}{x}+\dfrac{x}{z}=b,\ \dfrac{x}{y}+\dfrac{y}{x}=c$

[Example 6, Art 171, may be consulted with profit]

20. $x^2(y-z)=a,\ y^2(z-x)=b,\ z^2(x-y)=c,\ xyz=d$

21. Eliminate a, b, c from the equations

$$bz+cy=a,\ az+cx=b,\ ay+bx=c$$

II. Miscellaneous Theorems.

227. Theorem. *If the sum of the squares of any number of real quantities be zero, then each of the quantities is zero*

Let $A^2+B^2+C^2+D^2+\ \ldots=0$, where $A, B, C, D,$ are real quantities

To prove that $A=0, B=0, C=0, D=0, \ldots$

Proof. If the sum of any number of quantities be zero, evidently they must be partly positive and partly negative *unless each of them is zero*

Here, A, B, C, D, etc being real, their squares A^2 B^2, C^2, D^2, etc are *all* positive Hence, the sum of $A^2+B^2+C^2+D^2+\ldots$ cannot be zero unless each of A^2, B^2, C^2, etc is zero

$$A^2=0, \quad B^2=0, \quad C^2=0, \text{ etc}$$

i e, $$A=0, \quad B=0, \quad C=0, \text{ etc}$$

Example 1. If $a^2+b^2+c^2-bc-ca-ab=0$, prove that $a=b=c$, a, b, c being real.

We have $a^2+b^2+c^2-bc-ca-ab$

$$=\tfrac{1}{2}\{(b-c)^2+(c-a)^2+(a-b)^2\}=0$$

Hence, $b-c=0$, $c-a=0$ and $a-b=0$, *i e.*, $a=b=c$.

Example 2. If x, y, a and b be real, solve

$$(x-a)^2+(y-b)^2=0$$

Since, x, y, a and b are real, $(x-a)$ and $(y-b)$ are both real

From the given equation, we have

$$x-a=0, \text{ i e}, x=a; \text{ and } y-b=0, \text{ i e}, y=b$$

Example 3. Show that if $(x^2+y^2+z^2)(a^2+b^2+c^2)$

$$=(ax+by+cz)^2, \text{ then } \frac{x}{a}=\frac{y}{b}=\frac{z}{c}.$$

From the given relation, we have

$$a^2(y^2+z^2)+b^2(x^2+z^2)+c^2(x^2+y^2)=2abxy+2acxz+2bcyz$$

Hence, by transposition, $(a^2y^2+b^2x^2-2abxy)$

$$+(a^2z^2+c^2x^2-2acxz)+(b^2z^2+c^2y^2-2bcyz)=0$$

or, $$(ay-bx)^2+(az-cx)^2+(bz-cy)^2=0$$

Hence,
$$\left.\begin{array}{ll} ay-bx=0, & \therefore \dfrac{x}{a}=\dfrac{y}{b} \\ az-cx=0, & \therefore \dfrac{x}{a}=\dfrac{z}{c} \\ bz-cy=0; & \therefore \dfrac{y}{b}=\dfrac{z}{c} \end{array}\right\}$$

Thus we have $\dfrac{x}{a}=\dfrac{y}{b}=\dfrac{z}{c}$.

EXERCISE 123.

[*N B. Letters stand for real quantities in the following examples*]

1. If $(x+a)^2+(y+b)^2=4(xa+yb)$, prove that $x=a$, $y=b$

2. If $(x+a)^2+(y+b)^2+(z+c)^2=4(xa+yb+zc)$, prove that $x=a$, $y=b$ and $z=c$

3. If $a^2+b^2+c^2+bc+ca+ab=0$, prove that $a=b=c=0$

4. Solve $(x^2+y^2)(a^2+b^2)-(ax+by)^2+(y-b)^2=0$

5. Solve $x^2+y^2+2=(1+x)(1+y)$

6. Solve $x^2+2y^2+a^2=2y(x+a)$

7. Solve $2(x+y-1)=x^2+y^2+z^2$

8. Solve $1+ax+by=\sqrt{\{(1+x^2+y^2)(1+a^2+b^2)\}}$

228. Inequalities. If a and b be two real quantities, a is said to be $> b$, when $a-b$ is positive

Thus, $7>5$, since $7-5 = +2$,

$-3>-8$, since $(-3)-(-8)=+5$,

$a^2+1>2a$, since $a^2+1-2a=(a-1)^2=$ a positive quantity

An Inequality $a>b$ *is, therefore, established if* $a-b$ *can be proved to be positive*

Theorem. *If x and y be real and unequal, then*

$$x^2+y^2>2xy$$

$$(x^2+y^2)-(2xy)=x^2-2xy+y^2$$
$$=(x-y)^2=\text{a positive quantity},$$

$$x^2+y^2>2xy$$

Note *If* $x=y$, $(x^2+y^2)-(2xy)=(x-y)^2=0$,

i.e., $x^2+y^2=2xy$

Hence, x^2+y^2 *is never less than* $2xy$

Most of the results in Inequalities may be obtained by the application of the above theorem

Example 1. If x, y and z be real and unequal quantities, show that

$$x^2+y^2+z^2>yz+zx+xy.$$

We have $x^2+y^2>2xy$

$y^2+z^2>2yz,$

and $z^2+x^2>2zx$

Adding, $2(x^2+y^2+z^2)>2(xy+yz+zx),$

or, $x^2+y^2+z^2>yz+zx+xy.$

Otherwise $x^2+y^2+z^2-(yz+zx+xy)$

$=\frac{1}{2}[(y-z)^2+(z-x)^2+(x-y)^2]=$ a positive quantity;

$\therefore\ x^2+y^2+z^2>yz+zx+xy$

Example 2. If a, b, c be positive, real and unequal quantities, prove that

(i) $(b+c)(c+a)(a+b)>8abc,$

and (ii) $a^2(b+c)+b^2(c+a)+c^2(a+b)>6abc$

(i) We have $b+c=(\sqrt{b})^2+(\sqrt{c})^2>2\sqrt{b}\sqrt{c}.$

Similarly $c+a>2\sqrt{c}\sqrt{a}$

and $a+b>2\sqrt{a}\sqrt{b}$

Multiplying, $(b+c)(c+a)(a+b)>(2\sqrt{b}\sqrt{c})(2\sqrt{c}\sqrt{a})(2\sqrt{a}\sqrt{b})$

i.e., $>8abc.$

(ii) Also, $(b+c)(c+a)(a+b)$

$=a^2(b+c)+b^2(c+a)+c^2(a+b)+2abc>8abc;$

$\therefore\ a^2(b+c)+b^2(c+a)+c^2(a+b)>6abc$

EXERCISE 124.

[*N.B. Letters stand for real, positive and unequal quantities in the following examples.*]

Prove that:

1. $a^2-ab+b^2>ab$ **2.** $a^3+b^3>ab(a+b).$ **3.** $x+\frac{1}{x}>2.$

4. $\frac{a+b}{2}>\frac{2ab}{a+b}.$ **5.** $a+b+c>\frac{2bc}{b+c}+\frac{2ca}{c+a}+\frac{2ab}{a+b}.$

6. $(a+b+c)(bc+ca+ab)>9abc$ **7.** $a^3+b^3+c^3>3abc.$

8. $(a+b+c)^3-a^3-b^3-c^3>24abc.$

9. $(b^2-bc+c^2)(c^2-ca+a^2)(a^2-ab+b^2)>a^2b^2c^2.$

10. $a(b+c)^2+b(c+a)^2+c(a+b)^2>12abc.$

229. Theorem. If the fractions $\frac{a}{b}$, $\frac{c}{d}$, $\frac{e}{f}$, etc *be unequal,* then $\frac{a+c+e+\ldots}{b+d+f+\ldots}$ *is greater than the least and less than the greatest of them, the denominators b, d, f . . . .* **being positive.**

Let $\frac{a}{b}$ be the *smallest* of the fractions

Hence, $\frac{c}{d} > \frac{a}{b}$; $\frac{e}{f} > \frac{a}{b}$, and so on

Let $\frac{a}{b} = k$, $\therefore$ $\frac{c}{d} > k$, $\frac{e}{f} > k$, and so on

Hence, $a = bk$, $c > dk$, $e > fk$, etc.

Adding, $a+c+e+\ldots > bk+dk+fk+\ldots$

i e, $>(b+d+f+\ldots)k$,

$$\frac{a+c+e+\ldots}{b+d+f+\ldots} > k$$

i e $>$ the least of the fractions.

Similarly, $\frac{a+c+e+\ldots}{b+d+f+\ldots}$ can be proved to be less than the greatest of all fractions.

230. Maximum and Minimum Values of Expressions.

Example 1. Find the maximum values of $5-2x-x^2$ (i e, find the algebraically greatest value of $5-2x-x^2$ for various values of x)

The given expression

$$=5-2x-x^2=6-(1+2x+x^2)=6-(x+1)^2$$
$$=6+\{-(x+1)^2\}$$

Since, $(x+1)^2$ cannot be negative,

$\{-(x+1)^2\}$ can *never* be *positive*

Hence, whatever real value x may have, the given expression can *never* be *greater* than 6

Evidently, the given expression$=6$ when $x+1=0$, i e, when $x=-1$

Hence, we notice that the expression can be equal to 6 but can never be greater than 6

$\therefore$ the maximum value of the expression $=6$

Example 2. Find the minimum value of $4x^2+12x+18$ (i e, find the algebraically smallest possible value of $4x^2+12x+18$ for variours values of x)

The given expression $=(2x+3)^2+9$

Since. $(2x+3)^2$ cannot be negative, the given expression can *never* be less than 9 but can be equal to 9 when $2x+3=0$, i e, when $x=-1\frac{1}{2}$

$\therefore$ the smallest value required $=9$

EXERCISE 125.

Find the maximum value of

1. $6x-x^2-1$. **2.** $5+8x-8x^2$ **3.** $5+4x-4x^2$

4. $3+5x-2x^2$ **5.** $17+8x-x^2$

Find the minimum value of

6. $x^2+\dfrac{1}{x^2}+4$ **7.** $2x^2-7x+6$ **8.** $4x^2-9x+5$

9. $3x^2-5x+4$ **10.** $2x^2-13x+22$

11. Divide 32 into two parts so that their product has the maximum value

III. Miscellaneous Artifices.

231. We shall now work out some examples which require for their solution either the application of some principle with which the student is not already acquainted or some special artifice

Example 1. Express $(x+3a)(x+5a)(x+7a)(x+9a)$ as the difference of two square quantities

[C U Entr Paper, 1887]

The given expression

$$=\{(x+3a)(x+9a)\}\{(x+5a)(x+7a)\}$$
$$=\{x^2+12ax+27a^2\}\{x^2+12ax+35a^2\}$$
$$=\{(x^2+12ax+31a^2)-4a^2\}\{(x^2+12ax+31a^2)+4a^2\}$$
$$=(x^2+12ax+31a^2)^2-16a^4$$

Example 2. A man receives $\frac{x}{y}$ ths of Rs 10 and afterwards $\frac{y}{x}$ ths of Rs 10 He then gives away Rs 20. Show that he cannot lose by the transaction [C U Entr Paper, 1881]

The man receives altogether $\left(\frac{x}{y}+\frac{y}{x}\right)\cdot 10$ rupees and gives away 20 rupees

Clearly therefore he loses

$$\text{if } \left(\frac{x}{y}+\frac{y}{x}\right)\cdot 10 < 20,$$

i e, if $\frac{x}{y}+\frac{y}{x} < 2$,

i e if $x^2+y^2 < 2xy$,

i e, if $x^2+y^2-2xy < 0$,

i e, if $(x-y)^2$ be a negative quantity

But whichever of x and y may be the greater, $(x-y)^2$ can *never* be negative

Hence, the man *cannot* lose.

Note *It may be observed that there is always a gain in this transaction except when $x=y$*

Example 3. If $\frac{a}{b+c}+\frac{c}{a+b}=\frac{2b}{c+a}$, prove that

$$a^2+c^2=2b^2, \text{ or, } a+b+c=0$$

From the given relation, we have

$$\frac{a}{b+c}-\frac{b}{c+a}=\frac{b}{c+a}-\frac{c}{a+b},$$

$$\text{or,} \quad \frac{c(a-b)+a^2-b^2}{(b+c)(c+a)}=\frac{a(b-c)+b^2-c^2}{(c+a)(a+b)},$$

$$\text{or,} \quad \frac{(a-b)(c+\overline{a+b})}{b+c}=\frac{(b-c)(a+\overline{b+c})}{a+b},$$

$$\text{or,} \quad (a^2-b^2)(a+b+c)=(b^2-c^2)(a+b+c),$$

$$\text{or,} \quad (a+b+c)\{(a^2-b^2)-(b^2-c^2)\}=0,$$

$$\text{or,} \quad (a+b+c)(a^2+c^2-2b^2)=0$$

Therefore, either, $a+b+c=0$;

or, $a^2+c^2-2b^2=0$,

and . $a^2+c^2=2b^2$

Note *It may be observed in this connection that whenever any relation of equality is reduced to the form $xp=xp_1$, [or $x(p-p_1)=0$], it is obviously satisfied either (i) when $x=0$, or, (ii) when $p=p_1$, and that of these two alternative results we cannot accept one as the* **only** *conclusion to which we are led* **unless** *it is known that the other is impossible*

In the present example we have got $(a^2-b^2)(a+b+c)=(b^2-c^2)(a+b+c)$ as one of the steps in the solution, and it is not difficult to see from this that it would be a mistake to remove the common factor $a+b+c$ from both sides and set down $a^2-b^2=b^2-c^2$ as the next step, for the above relation may be true **not** *on account of a^2-b^2 being equal to b^2-c^2,* **but** *on account of $a+b+c$ being equal to* **zero** *We might remove $a+b+c$ from both sides of the equation however,* **if** *we know that owing to certain restrictions on the values of the letters a, b, c, the expression $a+b+c$ could not possibly vanish*

Hence the only legitimate conclusion from the relation $xp=xp_1$, [or $x(p-p_1)=0$], is "either $x=0$, or $p=p_1$" but **not** *simply "$p=p_1$"* ***except when** x is known to be* ***not equal to zero***

Example 4. Show that if $\frac{a-b}{c}+\frac{b-c}{a}+\frac{c+a}{b}=1$ and $a-b+c$ is *not*$=0$, then $\frac{1}{a}=\frac{1}{b}+\frac{1}{c}$. [C U Entr Paper, 1875.]

From the given relation, we have

$$1-\frac{b-c}{a}=\frac{a-b}{c}+\frac{c+a}{b},$$

or, $$\frac{a-b+c}{a}=\frac{b(a-b)+c(c+a)}{bc}$$

$$=\frac{b(a-b+c)+c(c+a-b)}{bc}$$

$$=\frac{(a-b+c)(b+c)}{bc}.$$

Hence, *either* $a-b+c=0$,

or, $\left.\frac{1}{a}=\frac{b+c}{bc}\right\}$ [See Note, last example]

But by hypothesis, $a-b+c$ is *not* zero

Therefore, we must have $\dfrac{1}{a}=\dfrac{b+c}{bc}=\dfrac{1}{b}+\dfrac{1}{c}$.

Example 5. If $a+b+c=0$, show that

$$2(a^4+b^4+c^4)=(a^2+b^2+c^2)^2.$$

From the given relation, we have

$$a+b=-c, \qquad a^2+2ab+b^2=c^2,$$

$$a^2+b^2-c^2=-2ab,$$

$$(a^2+b^2-c^2)^2=4a^2b^2,$$

or, $a^4+b^4+c^4+2a^2b^2-2a^2c^2-2b^2c^2=4a^2b^2$,

$$a^4+b^4+c^4=2(a^2b^2+b^2c^2+c^2a^2)$$

Hence, $2(a^4+b^4+c^4)=a^4+b^4+c^4+2(a^2b^2+b^2c^2+c^2a^2)$

$$=(a^2+b^2+c^2)^2$$

Example 6. If $a+b+c=0$, show that

$$\frac{1}{b^2+c^2-a^2}+\frac{1}{c^2+a^2-b^2}+\frac{1}{a^2+b^2-c^2}=0$$

From the given relation, we have

$$a+b=-c, \qquad . \; a^2+2ab+b^2=c^2,$$

$$a^2+b^2-c^2=-2ab$$

Similarly, $b^2+c^2-a^2=-2bc$, and $c^2+a^2-b^2=-2ca$

Hence, the proposed expression

$$=\frac{1}{-2bc}+\frac{1}{-2ca}+\frac{1}{-2ab}$$

$$=\frac{a+b+c}{-2abc}=\frac{0}{-2abc}=0$$

Example 7. If $a+b+c=0$, show that

$$\frac{a^2}{2a^2+bc}+\frac{b^2}{2b^2+ca}+\frac{c^2}{2c^2+ab}=1$$

We have $2a^2+bc=a^2+a\,a+bc$

$$=a^2-a(b+c)+bc \quad [\quad a=-(b+c)]$$

$$=(a-b)(a-c).$$

Similarly, $2b^2+ca=b^2-b(a+c)+ca=(b-c)(b-a)$,

and $$2c^2+ab=c^2-c(a+b)+ab$$
$$=(c-a)(c-b)$$

Hence, the proposed expression

$$=\frac{a^2}{(a-b)(a-c)}+\frac{b^2}{(b-c)(b-a)}+\frac{c^2}{(c-a)(c-b)}$$

$$=\frac{a^2}{(a-b)(a-c)}+\frac{-b^2}{(b-c)(a-b)}+\frac{c^2}{(a-c)(b-c)}$$

$$=\frac{a^2(b-c)-b^2(a-c)+c^2(a-b)}{(a-b)(a-c)(b-c)}$$

$$=\frac{a^2(b-c)+b^2(c-a)+c^2(a-b)}{(a-b)(a-c)(b-c)}$$

$$=\frac{(a-b)(a-c)(b-c)}{(a-b)(a-c)(b-c)}=1 \qquad \text{[Art 129]}$$

Example 8. Prove that $\left(x+\frac{1}{x}\right)^2+\left(y+\frac{1}{y}\right)^2+\left(z+\frac{1}{z}\right)^2$

$$=4+\left(x+\frac{1}{x}\right)\left(y+\frac{1}{y}\right)\left(z+\frac{1}{z}\right), \text{ if } xyz=1.$$

$$\left(x+\frac{1}{x}\right)^2+\left(y+\frac{1}{y}\right)^2=\left(x^2+2+\frac{1}{x^2}\right)+\left(y^2+2+\frac{1}{y^2}\right)$$

$$=4+\left(x^2+y^2\right)+\left(\frac{1}{x^2}+\frac{1}{y^2}\right)$$

$$=4+xy\left(\frac{x}{y}+\frac{y}{x}\right)+\frac{1}{xy}\left(\frac{y}{x}+\frac{x}{y}\right)$$

$$=4+\left(\frac{x}{y}+\frac{y}{x}\right)\left(xy+\frac{1}{xy}\right)$$

$$=4+\left(\frac{x}{y}+\frac{y}{x}\right)\left(\frac{1}{z}+z\right) \qquad [\quad xyz=1]$$

Hence, the given expression

$$=4+\left(\frac{x}{y}+\frac{y}{x}\right)\left(z+\frac{1}{z}\right)+\left(z+\frac{1}{z}\right)^2$$

$$=4+\left(z+\frac{1}{z}\right)\left(\frac{x}{y}+\frac{y}{x}+z+\frac{1}{z}\right)$$

$$=4+\left(z+\frac{1}{z}\right)\left\{\left(\frac{x}{y}+\frac{1}{z}\right)+\left(\frac{y}{x}+z\right)\right\}$$

$$=4+\left(z+\frac{1}{z}\right)\left\{\left(\frac{x}{y}+xy\right)+\left(\frac{y}{x}+\frac{1}{xy}\right)\right\},$$

[$\because xyz=1$]

$$=4+\left(z+\frac{1}{z}\right)\left\{x\left(\frac{1}{y}+y\right)+\frac{1}{x}\left(y+\frac{1}{y}\right)\right\}$$

$$=4+\left(z+\frac{1}{z}\right)\left(y+\frac{1}{y}\right)\left(x+\frac{1}{x}\right).$$

Example 9. If $xy+yz+zx=1$, show that

$$\frac{x}{1-x^2}+\frac{y}{1-y^2}+\frac{z}{1-z^2}=\frac{4xyz}{(1-x^2)(1-y^2)(1-z^2)}.$$

Since $xy+yz+zx=1$, we have

$$\left.\begin{aligned} xy+yz&=1-zx, \text{ or, } y(x+z)=1-zx \quad &(\text{i})\\ yz+zx&=1-xy \text{ or, } z(y+x)=1-xy \quad &(\text{ii})\\ zx+xy&=1-yz, \text{ or, } x(z+y)=1-yz \quad &(\text{iii})\end{aligned}\right\}$$

Now, the given expression

$$=\frac{x(1-y^2)(1-z^2)+y(1-z^2)(1-x^2)+z(1-x^2)(1-y^2)}{(1-x^2)(1-y^2)(1-z^2)}$$

of which the numerator

$$=x\{1-(y^2+z^2)+y^2z^2\}+y\{1-(z^2+x^2)+z^2x^2\}$$
$$+z\{1-(x^2+y^2)+x^2y^2\}$$
$$=(x+y+z)-y^2(z+x)-z^2(x+y)-x^2(y+z)$$
$$+xyz(yz+zx+xy)$$
$$=(x+y+z)-y\{y(z+x)\}-z\{z(x+y)\}-x\{x(y+z)\}+xyz\,1$$
$$=(x+y+z)-y(1-zx)-z(1-xy)-x(1-yz)+xyz,$$

[by (i), (ii) and (iii)]

$$=(x+y+z)-(y+z+x)+3xyz+xyz$$
$$=4xyz$$

Hence, the given expression $=\dfrac{4xyz}{(1-x^2)(1-y^2)(1-z^2)}.$

Example 10. If $x-a$ be the H C F of $a_1x^2+b_1x+c_1$ and $a_2x^2+b_2x+c_2$, prove that

$$\text{(i)}\quad a=\frac{c_1a_2-c_2a_1}{a_1b_2-a_2b_1};$$

$$\text{and (ii)}\quad (b_1c_2-b_2c_1)(a_1b_2-a_2b_1)=(c_1a_2-c_2a_1)^2$$

Since $x-a$ must be a factor of each of the expressions $a_1x^2+b_1x+c$ and $a_2x^2+b_2x+c_2$, we have by the factor theorem (Art 155),

$$a_1a^2+b_1a+c_1=0,$$
$$\text{and}\quad a_2a^2+b_2a+c_2=0$$

Hence, by cross multiplication,

$$\frac{a^2}{b_1c_2-b_2c_1}=\frac{a}{c_1a_2-c_2a_1}=\frac{1}{a_1b_2-a_2b_1};$$

$$\therefore\quad a=\frac{c_1a_2-c_2a_1}{a_1b_2-a_2b_1}.$$

Also, $$\frac{a^2}{b_1c_2-b_2c_1}\times\frac{1}{a_1b_2-a_2b_1}=\left(\frac{a}{c_1a_2-c_2a_1}\right)^2,$$

whence, $$(b_1c_2-b_2c_1)(a_1b_2-a_2b_1)=(c_1a_2-c_2a_1)^2$$

Example 11. By performing the operation for extracting the square root, find the value of x, which will make $x^4+6x^3+11x^2+3x+31$ a perfect square

$$\begin{array}{r|l}
 & x^4+6x^3+11x^2+3x+31\,(x^2+3x+1 \\
 & x^4 \\ \hline
2x^2+3x & 6x^3+11x^2 \\
 & 6x^3+\ 9x^2 \\ \hline
2x^2+6x+1 & 2x^2+3x+31 \\
 & 2x^2+6x+\ 1 \\ \hline
 & -3x+30
\end{array}$$

Now, in order that the given expression may be a perfect square, the remainder $(-3x+30)$ must be $=0$, and therefore $3x=30$, or, $x=10$

Hence, when $x=10$, the given expression is a perfect square

Example 12. If $x(b-c)+y(c-a)+z(a-b)=0$,

$$\text{then will}\quad \frac{bz-cy}{b-c}=\frac{cx-az}{c-a}=\frac{ay-bx}{a-b}.$$

We have $\left.\begin{array}{r} x(b-c)+y(c-a)+z(a-b)=0 \\ \text{and identically also, } a(b-c)+b(c-a)+c(a-b)=0 \end{array}\right\}$

Hence, by cross multiplication,

$$\frac{b-c}{cy-bz}=\frac{c-a}{az-cx}=\frac{a-b}{bx-ay};$$

whence, $$\frac{bz-cy}{b-c}=\frac{cx-az}{c-a}=\frac{ay-bx}{a-b}.$$

Example 13. Solve
$$\left.\begin{array}{lr} x+y+z=a+b+c & (1) \\ \dfrac{x}{a}+\dfrac{y}{b}+\dfrac{z}{c}=3 & (2) \\ \dfrac{x}{a^2}+\dfrac{y}{b^2}+\dfrac{z}{c^2}=\dfrac{1}{a}+\dfrac{1}{b}+\dfrac{1}{c} & (3) \end{array}\right\}$$

From (1), $(x-a)+(y-b)+(z-c)=0$

From (2), $\frac{1}{a}(x-a)+\frac{1}{b}(y-b)+\frac{1}{c}(z-c)=0$

Hence, by cross multiplication,

$$\frac{x-a}{\frac{1}{c}-\frac{1}{b}}=\frac{y-b}{\frac{1}{a}-\frac{1}{c}}=\frac{z-c}{\frac{1}{b}-\frac{1}{a}};$$

and supposing each of these fractions $=k$, we have

$$x-a=k\frac{b-c}{bc};\quad y-b=k\frac{c-a}{ca};\quad z-c=k\frac{a-b}{ab}. \qquad (\alpha)$$

Now from (3), $\frac{1}{a^2}(x-a)+\frac{1}{b^2}(y-b)+\frac{1}{c^2}(z-c)=0.$

Substituting in this equation the values of $x-a$, $y-b$, $z-c$, found above, we have

$$k\left\{\frac{b-c}{bc}\cdot\frac{1}{a^2}+\frac{c-a}{ca}\cdot\frac{1}{b^2}+\frac{a-b}{ab}\cdot\frac{1}{c^2}\right\}=0,$$

or, $$k\frac{bc(b-c)+ca(c-a)+ab(a-b)}{a^2b^2c^2}=0,$$

or, $$k\frac{(b-c)(a-b)(a-c)}{a^2b^2c^2}=0, \qquad \text{[Art 129]}$$

$$\therefore\quad k=0,$$

since, a, b, c being impliedly unequal, none of the factors $b-c$, $a-b$, $a-c$ is zero

Hence from (α),

$$\left.\begin{array}{lll} x-a=0, & \text{or,} & x=a \\ y-b=0, & \text{or,} & y=b \\ z-c=0, & \text{or,} & z=c \end{array}\right\}$$

Example 14. If $x=cy+bz$, $y=az+cx$ and $z=bx+ay$, show that $\dfrac{x^2}{1-a^2}=\dfrac{y^2}{1-b^2}=\dfrac{z^2}{1-c^2}$.

From the given relations, we have

$$\left.\begin{array}{ll} x-cy-bz=0 & (1) \\ cx-y+az=0 & (2) \\ bx+ay-z=0 & (3) \end{array}\right\}$$

From (1) and (2), by cross multiplication,

$$\frac{x}{-ac-b}=\frac{y}{-bc-a}=\frac{z}{-1+c^2},$$

$$\text{or,}\quad \frac{x}{ac+b}=\frac{y}{bc+a}=\frac{z}{1-c^2} \tag{4}$$

Similarly, from (2) and (3),

$$\frac{x}{1-a^2}=\frac{y}{ab+c}=\frac{z}{ac+b}, \tag{5}$$

and from (1) and (3),

$$\frac{x}{ab+c}=\frac{y}{1-b^2}=\frac{z}{bc+a} \tag{6}$$

Now, from (4) and (5),

$$\left.\begin{array}{r} \dfrac{x}{ac+b}=\dfrac{z}{1-c^2} \\ \text{and}\quad \dfrac{x}{1-a^2}=\dfrac{z}{ac+b} \end{array}\right\} \text{whence,}\quad \frac{x^2}{1-a^2}=\frac{z^2}{1-c^2}.$$

Again, from (5) and (6),

$$\left.\begin{array}{r} \dfrac{x}{1-a^2}=\dfrac{y}{ab+c} \\ \text{and}\quad \dfrac{x}{ab+c}=\dfrac{y}{1-b^2} \end{array}\right\} \text{whence,}\quad \frac{x^2}{1-a^2}=\frac{y^2}{1-b^2}.$$

Hence, $\dfrac{x^2}{1-a^2}=\dfrac{y^2}{1-b^2}=\dfrac{z^2}{1-c^2}$.

Example 15. Show that if $ax+by+cz=0$, and
$\frac{a}{x}+\frac{b}{y}+\frac{c}{z}=0$, then will

$$ax^2+by^2+cz^2+(a+b+c)(xy+yz+zx)=0$$

From the given relations, we have

$$\left.\begin{aligned} ax+by+cz&=0 \\ \text{and}\qquad ayz+bzx+cxy&=0 \end{aligned}\right\}$$

Hence, by cross multiplication,

$$\frac{a}{x(y^2-z^2)}=\frac{b}{y(z^2-x^2)}=\frac{c}{z(x^2-y^2)},$$

and each of these ratios

$$=\frac{ax^2+by^2+cz^2}{x^3(y^2-z^2)+y^3(z^2-x^2)+z^3(x^2-y^2)},$$

and also $=\dfrac{a+b+c}{x(y^2-z^2)+y(z^2-x^2)+z(x^2-y^2)}$. [Art 224]

Thus we have $\dfrac{ax^2+by^2+cz^2}{x^3(y^2-z^2)+y^3(z^2-x^2)+z^3(x^2-y^2)}$

$$=\frac{a+b+c}{x(y^2-z^2)+y(z^2-x^2)+z(x^2-y^2)}.$$

Hence, $\dfrac{ax^2+by^2+cz^2}{a+b+c}$

$$=\frac{x^3(y^2-z^2)+y^3(z^2-x^2)+z^3(x^2-y^2)}{x^2(z-y)+y^2(x-z)+z^2(y-x)}$$

$$=\frac{(y-z)(x-z)(x-y)(xy+yz+zx)}{-(y-z)(x-z)(x-y)}$$ [See Arts 140 and 129]

$$=-(xy+yz+zx);$$

whence, $ax^2+by^2+cz^2+(a+b+c)(xy+yz+zx)=0$

Example 16. If $\frac{x}{a}=\frac{y}{b}$, show that

$$\frac{x^3+a^3}{x^2+a^2}+\frac{y^3+b^3}{y^2+b^2}=\frac{(x+y)^3+(a+b)^3}{(x+y)^2+(a+b)^2}.$$

Let each of the given ratios $=k$ Then we have $x=ak$ and $y=bk$

Hence $\dfrac{x^3+a^3}{x^2+a^2}+\dfrac{y^3+b^3}{y^2+b^2}=\dfrac{a^3(k^3+1)}{a^2(k^2+1)}+\dfrac{b^3(k^3+1)}{b^2(k^2+1)}$

$$=\frac{a(k^3+1)}{k^2+1}+\frac{b(k^3+1)}{k^2+1}=\frac{(k^3+1)(a+b)}{k^2+1}$$

$$=\frac{(k^3+1)(a+b)^3}{(k^2+1)(a+b)^2}$$

$$=\frac{k^3(a+b)^3+(a+b)^3}{k^2(a+b)^2+(a+b)^2}$$

$$=\frac{(ka+kb)^3+(a+b)^3}{(ka+kb)^2+(a+b)^2}$$

$$=\frac{(x+y)^3+(a+b)^3}{(x+y)^2+(a+b)^2}.$$

Example 17. Show that $(bcd+cda+dab+abc)^2$
$-abcd(a+b+c+d)^2=(bc-ad)(ca-bd)(ab-cd)$

We have $(bcd+cda+dab+abc)^2$

$$=\{cd(a+b)+ab(c+d)\}^2$$
$$=c^2d^2(a+b)^2+2abcd(a+b)(c+d)+a^2b^2(c+d)^2\ ;$$

and $(a+b+c+d)^2=(a+b)^2+2(a+b)(c+d)+(c+d)^2$

Hence, the given expression

$$=c^2d^2(a+b)^2+a^2b^2(c+d)^2-abcd(a+b)^2-abcd(c+d)^2$$
$$=ab(c+d)^2(ab-cd)-cd(a+b)^2(ab-cd)$$
$$=(ab-cd)\{ab(c+d)^2-cd(a+b)^2\}$$
$$=(ab-cd)\{ab(c^2+d^2)-cd(a^2+b^2)\}$$
$$=(ab-cd)\{ac(bc-ad)-bd(bc-ad)\}$$
$$=(ab-cd)(bc-ad)(ac-bd)$$

Example 18. Show that the following expression is an exact square

$$(x^2-yz)^3+(y^2-zx)^3+(z^2-xy)^3-3(x^2-yz)(y^2-zx)(z^2-xy)$$

Putting a for x^2-yz, b for y^2-zx and c for z^2-xy, we have the given expression

$$=a^3+b^3+c^3-3abc$$
$$=(a+b+c)(a^2+b^2+c^2-bc-ca-ab) \quad \text{[Art 128]}$$
$$=\tfrac{1}{2}(a+b+c)\{(a-b)^2+(b-c)^2+(c-a)^2\} \quad . \ (1)$$

Now, $a-b=(x^2-yz)-(y^2-zx)$

$$=(x^2-y^2)+z(x-y)$$
$$=(x-y)(x+y+z)$$

Similarly, $\qquad b-c=(y-z)(x+y+z),$

and $\qquad c-a=(z-x)(x+y+z)\,,$

whence $\qquad (a-b)^2+(b-c)^2+(c-a)^2$

$$=(x+y+z)^2\{(x-y)^2+(y-z)^2+(z-x)^2\}$$

$$=2(x+y+z)^2(x^2+y^2+z^2-yz-zx-xy) \qquad (2)$$

Also, $a+b+c=x^2+y^2+z^2-yz-zx-xy \qquad (3)$

Therefore from (1), (2) and (3), the given expression

$$=\tfrac{1}{2}(x^2+y^2+z^2-yz-zx-xy)$$
$$\times\{2(x+y+z)^2(x^2+y^2+z^2-yz-zx-xy)\}$$
$$=\{(x+y+z)(x^2+y^2+z^2-yz-zx-xy)\}^2$$
$$=(x^3+y^3+z^3-3xyz)^2$$

Example 19. If $\dfrac{1}{a}+\dfrac{1}{b}+\dfrac{1}{c}=\dfrac{1}{a+b+c}$, show that

$$\left(\frac{1}{a}+\frac{1}{b}+\frac{1}{c}\right)^{2n+1}=\frac{1}{a^{2n+1}+b^{2n+1}+c^{2n+1}},$$

where n is any positive integer

From the given relation, we have

$$\frac{bc+a(b+c)}{abc}-\frac{1}{a+b+c}=0$$

$$\therefore \qquad \{a(b+c)+bc\}\{a+(b+c)\}-abc=0$$

Now, the left-hand expression

$$=a^2(b+c)+a(b+c)^2+bc(b+c)$$
$$=(b+c)\{a^2+a(b+c)+bc\}=(b+c)(a+b)(a+c)\,;$$
$$\therefore \qquad (b+c)(a+b)(a+c)=0$$

Hence, either $b+c=0$, or $a+b=0$, or, $a+c=0$

Taking $b+c=0$, we have $c=-b$

Hence, $\left(\dfrac{1}{a}+\dfrac{1}{b}+\dfrac{1}{c}\right)^{2n+1}=\left(\dfrac{1}{a}\right)^{2n+1} \quad \left[\because\ \dfrac{1}{b}+\dfrac{1}{c}=0\right]$

$$=\frac{1}{a^{2n+1}}=\frac{1}{a^{2n+1}+b^{2n+1}-b^{2n+1}}$$

$$=\frac{1}{a^{2n+1}+b^{2n+1}+c^{2n+1}}$$

[$\because\ c^{2n+1}=(-b)^{2n+1}=-b^{2n+1}$, see foot note, page 131]

The same result would follow if either $a+c$ or $a+b$ were taken equal to zero

Example 20. Having given $x=by+cz+du$, $y=ax+cz+du$, $z=ax+by+du$ and $u=ax+by+cz$, show that

$$\frac{a}{1+a}+\frac{b}{1+b}+\frac{c}{1+c}+\frac{d}{1+d}=1$$

Putting P for $ax+by+cz+du$, we have

$$x+ax=(by+cz+du)+ax$$
$$=P, \text{ or, } x(1+a)=P; \qquad \frac{1}{1+a}=\frac{x}{P}; \qquad (1)$$
$$y+by=(ax+cz+du)+by$$
$$=P, \text{ or, } y(1+b)=P, \qquad \frac{1}{1+b}=\frac{y}{P}; \qquad (2)$$
$$z+cz=(ax+by+du)+cz$$
$$=P, \text{ or, } z(1+c)=P, \qquad \frac{1}{1+c}=\frac{z}{P}; \qquad (3)$$
$$u+du=(ax+by+cz)+du$$
$$=P, \text{ or, } u(1+d)=P, \qquad \frac{1}{1+d}=\frac{u}{P}. \qquad (4)$$

nce, from (1), (2), (3) and (4), we have

$$\frac{a}{1+a}+\frac{b}{1+b}+\frac{c}{1+c}+\frac{d}{1+d}=\frac{ax}{P}+\frac{by}{P}+\frac{cz}{P}+\frac{du}{P}$$
$$=\frac{ax+by+cz+du}{P}=1.$$

Miscellaneous Exercises. VI

I

1. Find the value of $\sqrt{(x^2+y^3+z)(x-y-3y)}-\sqrt[3]{xy^8z^2}$, when $x=-1$, $y=-3$, $z=1$.

2. Simplify $3a-2(b-c)-\{2(a-b)-3(c+a)\}-\{9c-4(c-a)\}$

3. Resolve into factors $3(a+b)^2-2(a^2-b^2)-a(a+b)$,

4. Divide $2x^4-10x^3y+25x^2y^2-31xy^3+20y^4$ by $x^2-3xy+4y^2$

5. Simplify $\dfrac{b}{a+b}-\dfrac{ab}{(a+b)^2}-\dfrac{ab^2}{(a+b)^3}$.

6. Solve the equation $\frac{x+a}{x-a}-\frac{x-b}{x+b}=\frac{2(a+b)}{x}$.

7. If $\left(x+\frac{1}{x}\right)^2=3$, prove that $x^3+\frac{1}{x^3}=0$

8. Simplify $\frac{3\sqrt{3}-2\sqrt{2}}{\sqrt{3}-\sqrt{2}}$.

II

1. Find the value of $(2a+b)(a-b)+(2b+c)(b-c)$ $+(2c+a)(c-a)$ when $a=1$, $b=2$, $c=-3$

2. Divide $1+3x-24x^2+8x^4$ by $2x^2+3x-1$

3. If x^2+7x+c is exactly divisible by $x+4$, what is the value of c?

4. Simplify $\frac{1}{2\sqrt{7}-3\sqrt{2}}-\frac{1}{2\sqrt{7}+3\sqrt{2}}$.

5. Find the H C F of

$$x^4-3x^3-2x^2+12x-8 \text{ and } x^3-7x+6$$

6. Simplify $\left(1+\frac{35}{x-7}-\frac{15}{x-3}\right)\left(\frac{1}{5}-\frac{7}{x+7}+\frac{3}{x+3}\right)$.

7. Solve the equation $\frac{x+1}{6}+\frac{3x-1}{8}-\frac{5x-7}{12}+1=\frac{7x-5}{24}$.

8. If $x-\frac{1}{x}=1$, prove that $x^3-\frac{1}{x^3}=4$

III

1. Find the value of $\{a^2(b^3-c^3)+b^2(c^3-a^3)+c^2(a^3-b^3)\}$ $-(bc+ca+ab)$, when $a=3$, $b=-2$, $c=4$

2. Simplify $\frac{1+x}{1-x}+\frac{1-x}{1+x}-\frac{1+x^2}{1-x^2}-\frac{1-x^2}{1+x^2}$.

3. Resolve into factors $a^2-b^2+6bc-9c^2$

4. Find the H C F of

$x^3+5ax^2-5a^2x-a^3$ and $5x^3-3ax^2-5a^2x+3a^3$

5. Find the L C M of x^2-5x+6, x^2-4x+3 and x^2-3x+2.

6. Reduce to its lowest terms $\frac{x^5+5x^4+8x^3+4x^2}{x^5+x^4+8x^2+8x}$.

7. Solve $\frac{1}{x+3}+\frac{1}{x-2}=\frac{2}{x-7}$.

8. If $a \quad b \quad x \quad y$, show that $ab \cdot xy \quad a^2+b^2 \quad x^2+y^2$

IV

1. Simplify $\dfrac{\sqrt{x^2-y^2}+x}{\sqrt{x^2+y^2}+y} - \dfrac{\sqrt{x^2+y^2}-y}{x-\sqrt{x^2-y^2}}$.

2. If the product of two expressions be $x^8+x^4y^4+y^8$ and one of them be x^2-xy+y^2, find the other

3. Resolve into factors

(i) x^3+x^2-x-1, (ii) $a^2b^2-a^2-b^2+1$

4. Show that $(ax+by)^2+(bx-ay)^2=(a^2+b^2)(x^2+y^2)$

5. Find the L C.M of

$$8x^3+27,\ 16x^4+36x^2+81 \text{ and } 6x^2-5x-6$$

6. Solve $\dfrac{3x-4}{x}+\dfrac{2}{4x+3}=3$

7. Find x and y, if $\dfrac{bx+ay}{2ab}=\dfrac{by-ax}{b^2-a^2}=ab$

8. If $\dfrac{x}{a+b-c}=\dfrac{y}{a-b+c}=\dfrac{z}{b+c-a}$, show that each of these fractions $=\dfrac{x+y+z}{a+b+c}$.

V

1. Simplify $\dfrac{x^2-25y^2}{x^2+3xy-10y^2} \times \dfrac{x^2-4y^2}{x^2-3xy-10y^2}$.

2. Divide $a^3(b-c)+b^3(c-a)+c^3(a-b)$ by $a+b+c$, and find the factors of the quotient

3. Find the value of $\dfrac{x^3-y^3}{x^3+y^3}$, when $x=a+3$, $y=a-3$

4. Find the square root of

$$24+\frac{x^2}{y}+8\left(\frac{2y}{x^2}-xy^{-\frac{1}{2}}\right)-\frac{32\sqrt{y}}{x}.$$

5. Show that $(a^2+b^2+c^2)(x^2+y^2+z^2)-(ax+by+cz)^2$
$=(ay-bx)^2+(bz-cy)^2+(cx-az)^2$.

6. Subtract $\dfrac{7-2\sqrt{5}}{4-\sqrt{5}}$ from $\dfrac{15+6\sqrt{5}}{2+\sqrt{5}}$.

7. Solve $\left.\begin{aligned} 2^x \times 4^y &= 32 \\ 3^x - 9^y &= 3 \end{aligned}\right\}$

8. If $a \quad b \quad c \quad d$, show that $(a^2+c^2)(b^2+d^2)=(ab+cd)^2$

VI

1. Reduce to its simplest form the expression

$$\frac{2a(1-x^2)^2}{yz} \div \frac{(1+x)^2(1-x)}{y^3} \div \frac{2ay^2(1-x)}{z}.$$

2. Multiply $a+b+\frac{b^2}{a}+\frac{a^2}{b}$ by $a-b+\frac{b^2}{a}-\frac{a^2}{b}$.

3. Divide $x^4-2bx^3-(a^2-b^2)x^2+2a^2bx-a^2b^2$ by $x^2-(a+b)x+ab$

4. If $a=y+z$ $b=z+x$, $c=x+y$, then $a^2+b^2+c^2-bc-ca-ab=x^2+y^2+z^2-yz-zx-xy$.

5. Reduce $\frac{5x^3-14x^2+16}{3x^3-2x^2+16x-48}$ to its lowest terms

6. Solve $\frac{2}{x}+\frac{7}{y}=29$, $\frac{5}{x}-\frac{6}{y}=2$

7. Solve $2x+3y-8z+35=0$, $7x-4y+z-8=0$, $12x-5y-3z+10=0$

8. If $a \quad b=c \quad d=e \quad f$, prove that $a \,.\, b \quad \sqrt{m^2a^2+n^2c^2-p^2e^2} \cdot \sqrt{m^2b^2+n^2d^2-p^2f^2}$.

VII

1. Divide $-2x^5y^{-8}+17x^6y^{-4}-5x^7-24x^8y^4$ by $-x^2y^{-5}+7x^3y^{-1}+8x^4y^3$

2. Find the H C F. of $e^{2x}a^3+e^{2x}-a^3-1$ and $e^{2x}a^2+2e^xa^2-e^{2x}-2e^x+a^2-1$

3. Show that

$$1-\frac{a^2+b^2-c^2-d^2}{2(ab+cd)}=\frac{(a+c+d-b)(b+c+d-a)}{2(ab+cd)}.$$

4. Simplify $\frac{ab(x^2+y^2)+xy(a^2+b^2)}{ab(x^2-y^2)+xy(a^2-b^2)}$.

5. Solve $\frac{x-4}{x-5}-\frac{x-5}{x-6}=\frac{x-7}{x-8}-\frac{x-8}{x-9}$.

6. Show that if each of the expressions x^2+px+q and $x^2+p'x+q'$ be divisible by $x+a$, then $a=\dfrac{q-q'}{p-p'}$.

7. A bill of £100 was paid with guineas and half-crowns, and 48 more half-crowns than guineas were used, find how many of each were paid

8. If $a \;\; b : c \;\; d$, prove that

$$4a^6+5b^6 : 4c^6+5d^6 \quad a^3b^3 \cdot c^3d^3.$$

VIII

1. Show that $(ax+by+cz)^3+(cx-by+az)^3$ is divisible by $(a+c)(x+z)$

2. Resolve into factors.

(i) $(b+c)^2-6a(b+c)+5a^2$; (ii) $x^2+2xy-a^2-2ay$.

3. Simplify $\dfrac{(a+b)\{(a+b)^2-c^2\}}{4b^2c^2-(a^2-b^2-c^2)^2}$.

4. If $a+b+c=0$, show that $a^2-bc=b^2-ca=c^2-ab$

5. Solve $3(x+3)^2+5(x+5)^2=8(x+8)^2$

6. Extract the square root of

$$25x^{-2}-12x+16x^{-8}+4x^4-24x^{-5}$$

7. Find the value of x, y, z, if $yz=4$, $zx=9$, $xy=25$

8. If $a \cdot b \quad c \quad d$, show that $a(a+b+c+d)=(a+b)(a+c)$.

IX

1. Find the value of

$$\{a^2-(b-c)^2\}-\{b^2-(c-a)^2\}-\{c^2-(a-b)^2\}$$

when $a=1$, $b=2$ and $c=-3$

2. Simplify $\dfrac{x}{(x-1)^2}-\dfrac{1}{(x+1)^2}-\dfrac{x(x^2+3)}{(x^2-1)^2}$.

3. Resolve into factors $a^3-b^3+3ab+1$

4. Solve $\dfrac{4x+3}{9}+\dfrac{7x-29}{5x-12}=\dfrac{8x+19}{18}$.

5. Show that

$$\frac{1}{(y-z)^2}+\frac{1}{(z-x)^2}+\frac{1}{(x-y)^2}=\left(\frac{1}{y-z}+\frac{1}{z-x}+\frac{1}{x-y}\right)^2.$$

6. Solve $x+y \quad x-y=5 \quad 3, x+5y=36$

7. Find the time between 8 and 9 o'clock, when the hands of a clock are at right angles to each other

8. If $a \quad b \cdot b \quad c$, show that

$$(a+b+c)(a-b+c)=a^2+b^2+c^2.$$

X.

1. Divide $27a^3-8b^3-27c^3-54abc$ by $3a-2b-3c$.

2. Find the H C F of x^5+11x^3-54 and $x^5+11x+12$

3. Resolve into factors $(a^2-b^2)(x^2+y^2)+2(a^2+b^2)xy$

4. Simplify $$\frac{\dfrac{a^2}{b^2}+\dfrac{b^2}{a^2}-2}{\dfrac{a^2}{b^2}+\dfrac{b^2}{a^2}+2} \div \frac{\dfrac{a}{b}\left(1-\dfrac{b^2}{a^2}\right)}{\dfrac{(a+b)^2}{ab}-2}.$$

5. Show that $a^3(b+c)+b^3(c+a)+c^3(a+b)+abc(a+b+c)$
$$=(a^2+b^2+c^2)(bc+ca+ab).$$

6. Solve $\sqrt{9+2x}-\sqrt{2x}=\dfrac{5}{\sqrt{9+2x}}$.

7. One man and two boys can do in 12 days a piece of work which would be done in 6 days by 3 men and 1 boy How long would it take one man to do it?

8. If $a \quad b \quad b \quad c$, prove that

$$a^4+a^2c^2+c^4=b^2\left(\frac{b^2}{c^2}-1+\frac{b^2}{a^2}\right)(a^2+b^2+c^2)$$

XI.

1. Show that $(x^2+xy+y^2)^2-4xy(x^2+y^2)=(x^2-xy+y^2)^2$.

2. Resolve into factors

(i) $a^2-b^2-c^2+d^2-2(ad-bc)$,

(ii) $x^2-y^2-z^2+2yz+x+y-z$.

3. Extract the square root of $\dfrac{9x^2}{a^2}+\dfrac{a^2}{9x^2}-\dfrac{6x}{a}-\dfrac{2a}{3x}+3$

4. Solve $x+2y+3z=6, 2x+4y+z=7 \quad 3x+2y+9z=14$

5. Find the H C F of $x^4y-x^3y^2-15x^2y^3+38xy^4-14y^5$ and $x^5-7x^4y+21x^3y^2-34x^2y^3+28xy^4$

6. A man buys 570 oranges, some at 16 for a shilling and the rest at 18 for a shilling, he sells them all at 15 for a shilling and gains three shillings; how many for each sort does he buy?

7. Simplify

$$\frac{1}{\left(1-\frac{c}{a}\right)\left(1-\frac{b}{a}\right)}+\frac{1}{\left(1-\frac{a}{b}\right)\left(1-\frac{c}{b}\right)}+\frac{1}{\left(1-\frac{b}{c}\right)\left(1-\frac{a}{c}\right)}.$$

8. If $a : b=c : d=e : f$, prove that

$$(a^2+c^2+e^2)(b^2+d^2+f^2)=(ab+cd+ef)^2$$

XII.

1. If $x=a+d$, $y=b+d$, $z=c+d$, show that

$$x^2+y^2+z^2-yz-zx-xy=a^2+b^2+c^2-bc-ca-ab$$

2. Simplify

$$\frac{y+z}{(y^2-xz)(z^2-xy)}+\frac{z+x}{(z^2-xy)(x^2-yz)}+\frac{x+y}{(x^2-yz)(y^2-xz)}.$$

3. Resolve into factors

(i) $x^2-2ax-b^2+2ab$;

(ii) $x^2+(a+b+c)x+ab+ac$

4. Find the H C F of

$$6x^4-2x^3+9x^2+9x-4 \text{ and } 9x^4+80x^2-9$$

5. Solve $\dfrac{6x+13}{15}-\dfrac{3x+5}{5x-25}-\dfrac{2x}{5}=0$

6. A and B can together do a work in 12 days, A and C in 15 days, B and C in 20 days; find in how many days they will do the work, all working together

7. Simplify $4\sqrt{147}-3\sqrt{75}-6\sqrt{\frac{1}{3}}+18\sqrt{\frac{1}{27}}$.

8. Show that, if $x : y :: a : b$, then will

$$\frac{x^2+a^2}{x+a}+\frac{y^2+b^2}{y+b}=\frac{(x+y)^2+(a+b)^2}{x+y+a+b}.$$

XIII

1. If $2s=a+b+c$, show that

$$a(b-c)(s-a)^2+b(c-a)(s-b)^2+c(a-b)(s-c)^2=0.$$

2. Show that $x^6+x^3a^3+a^6$ is divisible by $x^{\frac{3}{4}}+x^{\frac{3}{8}}a^{\frac{3}{8}}+a^{\frac{3}{4}}$

3. Simplify $\dfrac{x^2-yz}{(x+y)(x+z)}+\dfrac{y^2-zx}{(y+z)(y+x)}+\dfrac{z^2-xy}{(z+x)(z+y)}$,

4. Solve $\dfrac{x^2-a^2}{x-a}+\dfrac{x^2-b^2}{x-b}+\dfrac{x^2-c^2}{x-c}=a+b+c-3x$

5. Find how many gallons of water must be mixed with 80 gallons of spirit which cost 15 shillings a gallon, so that by selling the mixture at 12 shillings a gallon there may be a gain of 10 per cent, on the outlay

6. Simplify $\dfrac{(x^{a+b})^2\,(x^{b+c})^2\,(x^{c+a})^2}{(x^a\,x^b\,x^c)^4}$.

7. Simplify $3\sqrt[3]{128}-4\sqrt[3]{-686}+2\sqrt[3]{54}$

8. If $a \quad b \quad b \cdot c$, prove that

$$a^2+ab+b^2 \quad b^2+bc+c^2 \quad a \quad c$$

XIV

1. If $a+b+c=2s$, and $a^2+b^2+ab+s^2=2s(a+b)$, show that $(a-s)^2+(b-s)^2+(c-s)^2=s^2$

2. If $x+a$ be a common factor of x^2+px+q and x^2+lx+m, show that $a=\dfrac{m-q}{p-l}$.

3. Simplify $\dfrac{7+3\sqrt{5}}{7-3\sqrt{5}}+\dfrac{7-3\sqrt{5}}{7+3\sqrt{5}}$.

4. Solve $\dfrac{a-b}{x-a}+\dfrac{a-b}{x-b}=\dfrac{a}{x-a}-\dfrac{b}{x-b}$.

5. Solve $\dfrac{y+z-x}{b+c}=\dfrac{z+x-y}{c+a}=\dfrac{x+y-z}{a+b}=1$.

6. A can do a piece of work in 20 days, which B can do in 12 days A begins the work, but after a time B takes his place, and the whole work is finished in 14 days from the beginning How long did A work?

7. Express $(x+a)(x+2a)(x+3a)(x+4a)$ as the difference of two squares

8. Show that if $a(y+z)=b(z+x)=c(x+y)$, then

$$\frac{y-z}{a(b-c)}=\frac{z-x}{b(c-a)}=\frac{x-y}{c(a-b)}.$$

XV.

1. For what value of b will

$x^4+2ax^3+(a^2+8)x^2+(4a+ab)x+4b$ be a perfect square ?

2. Prove that $(b-c)(1+ab)(1+ac)+(c-a)(1+bc)(1+ba)$
$+(a-b)(1+ca)(1+cb)=(b-c)(c-a)(a-b)$.

3. Simplify

$$\frac{2x^2+2}{x^4+x^2+1}+\frac{1}{x+\sqrt{x}+1}+\frac{1}{x-\sqrt{x}+1}-\frac{1}{x^2-x+1}.$$

4. Find the H C F of $2x^3+(2a-3b)x^2-(2b+3ab)x+3b^2$ and $2x^2-(3b-2c)x-3bc$

5. Find the value of

$$\frac{a^n}{2na^n-2nx}+\frac{b^n}{2nb^n-2nx}, \quad \text{when } x=\frac{a^n+b^n}{2}.$$

6. Solve $\dfrac{20x+36}{25}+\dfrac{5x+20}{9x-16}=\dfrac{4x}{5}+\dfrac{86}{25}$.

7. A vessel is filled with a mixture of spirit and water, 70 per cent of which is spirit After 9 gallons are taken out and the vessel is filled up with water, there remains $58\frac{1}{3}$ per cent of spirit, find the contents of the vessel.

8. If $x-z \quad y-z \quad x^2 \quad y^2$, show that

$$x+z \quad y+z\,. \quad \frac{x}{y}+2 \quad \frac{y}{x}+2$$

XVI

1. Find the H C F of $x^5+2x^4-5x^2-7x+3$ and
$3x^6-3x^4-18x^3+x^2+2x+3$.

2. Solve $\sqrt{2x-1}+\sqrt{3x-2}=\sqrt{4x-3}+\sqrt{5x-4}$

3. If $(a+b+c)x=(-a+b+c)y=(a-b+c)z=(a+b-c)w$,

show that $\dfrac{1}{y}+\dfrac{1}{z}+\dfrac{1}{w}=\dfrac{1}{x}$.

4. Solve

$$\left.\begin{aligned}\frac{5\sqrt{x+y}}{x}+\frac{5\sqrt{x+y}}{y}&=10\tfrac{2}{3}\\ \frac{3\sqrt{x-y}}{y}-\frac{3\sqrt{x-y}}{x}&=\frac{4}{5}\end{aligned}\right\}$$

5. Resolve into factors $ax(y^3+b^3)+by(bx^2+a^2y)$.

6. Find the continued product of $\sqrt{a}+\sqrt{b}+\sqrt{c}$, $\sqrt{a}+\sqrt{b}-\sqrt{c}$, $\sqrt{a}-\sqrt{b}+\sqrt{c}$, $\sqrt{b}+\sqrt{c}-\sqrt{a}$

7. If $\dfrac{a+b}{a-b}=\dfrac{c}{d}$, show that $\dfrac{a^2+ab}{ab-b^2}=\dfrac{c^2+cd}{cd-d^2}$.

8. Each of two vessels contains a mixture of wine and water; a mixture consisting of equal measures from the two vessels contains as much wine as water, and another mixture consisting of four measures from the first vessel and one from the second is composed of wine and water in the ratio of 2 3 Find the proportion of wine and water in each of of the vessels

XVII.

1. Find the H C F of x^5+x^2+2x+2 and x^4+x^2+1

2. Solve $\left.\begin{array}{l}\sqrt{y}-\sqrt{y-x}=\sqrt{20-x}\\ \sqrt{y-x} \quad \sqrt{20-x} \quad 3 \quad 2\end{array}\right\}$

3. Find the value of

$$\left(\frac{x}{x-1}\right)^2+\left(\frac{x}{x+1}\right)^2, \text{ when } x=\sqrt{\frac{n-1}{n+1}}.$$

4. Show that

$$\frac{a^3(b^2-c^2)+b^3(c^2-a^2)+c^3(a^2-b^2)}{a^2(b-c)+b^2(c-a)+c^2(a-b)}=ab+bc+ca$$

5. If $a+b+c=0$, show that

$$4(b^2c^2+c^2a^2+a^2b^2)=(a^2+b^2+c^2)^2$$

Hence, prove that

$$(y-z)^2(z-x)^2+(z-x)^2(x-y)^2+(x-y)^2(y-z)^2$$
$$=(x^2+y^2+z^2-yz-zx-xy)^2.$$

6. One of the digits of a number is greater by 5 than the other When the digits are inverted the number becomes $\frac{3}{8}$ of the original number Find the number

7. Simplify $\dfrac{3x^3+x^2-5x+21}{6x^3+29x^2+26x-21}$.

8. If $3(a^2+b^2+c^2)=(a+b+c)^2$, show that $a=b=c$

XVIII

1. Show that $\{(x-y)^2+(y-z)^2+(z-x)^2\}^2$

$$=2\{(x-y)^4+(y-z)^4+(z-x)^4\}.$$

2. Solve $\dfrac{x+\sqrt{x^2-a^2}}{x-\sqrt{x^2-a^2}}=4\sqrt{2}\left\{\dfrac{\sqrt{x+a}-\sqrt{x-a}}{\sqrt{x+a}+\sqrt{x-a}}\right\}^{\frac{1}{2}}$

3. Resolve into factors :

(i) $14x^2-37x+5$, (ii) $(1+a)^2(1+c^2)-(1+c)^2(1+a^2)$;

(iii) $m^4-n^4+2n(m^3+n^3)-(m+n)^2(m-n)^2$.

4. A baker charges $9\frac{1}{2}d$ for a loaf which he represents as weighing 4 lbs, but which really weighs 3 lbs 12 oz After he has sold a certain number of loaves, he is detected and fined £5, and thus loses five shillings more than he has cleared by selling short weight How many loaves does he sell ?

5. Simplify $\dfrac{a^3}{(a-b)(a-c)}+\dfrac{b^3}{(b-c)(b-a)}+\dfrac{c^3}{(c-a)(c-b)}$.

6. If $\dfrac{a-b}{ay+bx}=\dfrac{b-c}{bz+cy}=\dfrac{c-a}{cx+az}=\dfrac{a+b+c}{ax+by+cz}$, then each of these ratios $=\dfrac{1}{x+y+z}$, supposing $a+b+c$ not to be zero

7. Solve $x(x+y+z)=24$, $y(x+y+z)=48$, $z(x+y+z)=72$.

8. Eliminate x from the equations

$$\left.\begin{aligned} a+c&=\frac{b}{x}-dx \\ a-c&=\frac{d}{x}-bx \end{aligned}\right\}$$

XIX

1. Solve $(x^2-2ax+3a^2)^{\frac{1}{2}}+(x^2-4ax+5a^2)^{\frac{1}{2}}$

$$=(x^2-5ax+7a^2)^{\frac{1}{2}}+(x^2-7ax+9a^2)^{\frac{1}{2}}.$$

2. Show that

$$\frac{a(a+b)(a+c)}{(a-b)(a-c)}+\frac{b(b+a)(b+c)}{(b-a)(b-c)}+\frac{c(c+a)(c+b)}{(c-a)(c-b)}=a+b+c$$

3. Simplify $\dfrac{(b-c)a^3+(c-a)b^3+(a-b)c^3}{c^2-bc-ca+ab}$.

4. If m gold coins are equal in weight to n silver coins and p of the former equal in value to q of the latter, compare the values of equal weights of gold and silver

5. If $x=b+c$, $y=c+a$, $z=a+b$, show that

$$x^3+y^3+z^3-3xyz=2(a^3+b^3+c^3-3abc)$$

6. If $\dfrac{1}{b^3(a-c)}+\dfrac{1}{a^3(b-c)}=\dfrac{1}{ab(a-c)(b-c)}$, prove that

$$\frac{1}{a}+\frac{1}{b}=\frac{1}{c}, \quad \text{or, } a^2+b^2=ab$$

7. Simplify $\sqrt{\dfrac{(\sqrt{12}-\sqrt{8})(\sqrt{3}+\sqrt{2})}{5+\sqrt{24}}}$.

8. Eliminate x and y from the equations

$$(b+c)x+(c+a)y+(a+b)=0,\ (c+a)x+(a+b)y+(b+c)=0,$$
$$(a+b)x+(b+c)y+(c+a)=0$$

XX

1. Show that $a(b+c)^2+b(c+a)^2+c(a+b)^2-4abc$

$$=(b+c)(c+a)(a+b)$$

2. If $x+a$ be a factor of $a^2x^3-b^3x^2+ac^3x+3a^3bc$, and if a is not equal to zero, show that $a^3+b^3+c^3=3abc$.

3. Simplify

$$\frac{bc}{a(a^2-b^2)(a^2-c^2)}+\frac{ac}{b(b^2-a^2)(b^2-c^2)}+\frac{ab}{c(c^2-b^2)(c^2-a^2)}.$$

4. Divide $a^4(b-c)+b^4(c-a)+c^4(a-b)$

by $(a-b)(b-c)(c-a)$.

5. If $a+b+c=0$, show that $a^5+b^5+c^5=5abc(c^2-ab)$

6. Solve $\dfrac{a}{x+a-c}+\dfrac{b}{x+b-c}=2$

7. Solve $ax+by+cz=a+b+c$, $\dfrac{ax}{b+c}+\dfrac{by}{a+c}=1$,

$$\frac{2x}{b+c}+\frac{2y}{a+c}=\frac{1}{a}+\frac{1}{b}.$$

8. A person starts to walk at a uniform speed without stopping from Cuttack to Jobra and back, at the same time another starts to walk at a uniform speed without stopping from Jobra to Cuttack and back They meet a mile and a

half from Jobra and again, an hour after, a mile from Cuttack Find their rates of walking, and the distance between Cuttack and Jobra

XXI

1. Show that

$$\{(b+c)^2+(c+a)^2+(a+b)^2\}\times\{a^2(b-c)+b^2(c-a)+c^2(a-b)\}$$
$$=2\{a^4(b-c)+b^4(c-a)+c^4(a-b)\}.$$

2. Show that $\dfrac{(b-c)^2}{(c-a)(a-b)}+\dfrac{(c-a)^2}{(a-b)(b-c)}+\dfrac{(a-b)^2}{(b-c)(c-a)}=3.$

3. If $a+b+c=0$, show that

$$a^2+ab+b^2=b^2+bc+c^2=c^2+ca+a^2.$$

4. If $s=a+b+c$, prove that

$$(s-3a)^2+(s-3b)^2+(s-3c)^2=3\{(a-b)^2+(b-c)^2+(c-a)^2\}.$$

5. Resolve into factors $a^2+2ab-2ac-3b^2+2bc.$

6. Find the H C F of $x^4-2x^3+5x^2-4x+3$ and

$$2x^4-x^3+6x^2+2x+3$$

7. Find the condition that ax^3+bx+c and $a'x^3+b'x+c'$ may have a common factor of the *form* $x+f$

8. If $a : b=b : c=c : d$, prove that

$$a : d=\sqrt{a^5+b^2c^2+a^3c^2} : \sqrt{b^4c+d^4+b^2cd^2}.$$

XXII.

1. Show that $a(b-c)(1+ab)(1+ac)+b(c-a)(1+bc)(1+ba)$

$$+c(a-b)(1+ca)(1+cb)=abc(a-b)(a-c)(b-c)$$

2. If $a+b+c=0$, show that if $a^7+b^7+c^7=7abc(c^2-ab)^2.$

3. Show that if ax^2+bx+c and $a'x^2+b'x+c'$ have a common factor of the *form* $x+f$, then will $(ac'-a'c)^2=(bc'-b'c)(ab'-a'b)$

4. A and B run a race, B has 50 yards start, but A runs 20 yards while B runs 19 What must be the length of the course that A may come in a yard ahead of B?

5. Show that $\dfrac{p+q+r}{p-q}-\dfrac{q(4p+3r)-r(p+r)}{p^2-q^2}=\dfrac{(p-q+r)^2}{p^2-q^2}.$

6. Show that

$$\frac{(a^2-b^2)^3+(b^2-c^2)^3+(c^2-a^2)^3}{(a-b)^3+(b-c)^3+(c-a)^3}=(a+b)(b+c)(c+a)$$

7. Solve

$$x+y+z=2a+2b+2c,\quad ax+by+cz=2bc+2ca+2ab,$$
$$(b-c)x+(c-a)y+(a-b)z=0$$

8. Eliminate x, y, z from the equations

$$ax+cy+bz=0,\ cx+by+az=0,\ bx+ay+cz=0.$$

XXIII

1. Show that $(b-c)(1+a^2b)(1+a^2c)$
$$+(c-a)(1+b^2c)(1+b^2a)+(a-b)(1+c^2a)(1+c^2b)$$
$$=abc(a+b+c)(a-b)(a-c)(b-c)$$

2. Find the L C M of $21x^2-13x+2$, $28x^2-15x+2$ and $12x^2-7x+1$

3. Show that $(x+y)^7-x^7-y^7$ is divisible by $(x^2+xy+y^2)^2$.

4. If $2s=a+b+c$ and $2t^2=a^2+b^2+c^2$, show that
$$(t^2-a^2)(t^2-b^2)+(t^2-b^2)(t^2-c^2)+(t^2-c^2)(t^2-a^2)$$
$$=4s(s-a)(s-b)(s-c)$$

5. If $(1+xx'+yy')^2=(1+x^2+y^2)(1+x'^2+y'^2)$, show that $x=x'$ and $y=y'$.

6. Simplify

$$\frac{ab(a-b)(a^2+b^2)+bc(b-c)(b^2+c^2)+ca(c-a)(c^2+a^2)}{a^2b^2(a-b)+b^2c^2(b-c)+c^2a^2(c-a)}.$$

7. If $a+b+c=0$, prove that

$$\frac{a^5+b^5+c^5}{5}=\frac{a^3+b^3+c^3}{3}\cdot\frac{a^2+b^2+c^2}{2}.$$

8. Eliminate x and y from the equations

$$ax+by=\sqrt{a^2+b^2},\quad \frac{x^2}{p^2}+\frac{y^2}{q^2}=\frac{1}{a^2+b^2},\quad x^2+y^2=1.$$

XXIV

1. Solve $x+y+z=a+b+c$,
$$bx+cy+az=cx+ay+bz=ab+bc+ca$$

2. Divide 243 into three parts such that one half of the first, one-third of the second and one-fourth of the third part shall all be equal to one another

3. If $4(a^2+b^2+c^2+d^2)=(a+b+c+d)^2$, show that $a=b=c=d$

4. If $2s=a+b+c$, show that

$$a(b-c)(s-a)^2+b(c-a)(s-b)^2+c(a-b)(s-c)^2=0.$$

5. If $bz+cy=a$, $az+cx=b$ and $ay+bx=c$, prove that

$$\frac{a^2}{1-x^2}=\frac{b^2}{1-y^2}=\frac{c^2}{1-z^2}.$$

6. Eliminate x and y from the equations

$$ax+by=x+y+xy=x^2+y^2-1=0$$

7. If ax^2-bx+c and dx^3-bx+c have a common factor, show that $a^3-abd+cd^2=0$

8. If $a^3+b^3+c^3=(a+b+c)^3$, then will

$$a^{2n+1}+b^{2n+1}+c^{2n+1}=(a+b+c)^{2n+1},$$

where n is any positive integer.

XXV

1. If $x=a^2-bc$, $y=b^2-ca$, $z=c^2-ab$, prove that

$$\frac{x^2-yz}{a}=\frac{y^2-zx}{b}=\frac{z^2-xy}{c}=(a+b+c)(x+y+z)$$

2. If $2s=a+b+c+d$, show that

$$4(bc+ad)^2-(b^2+c^2-a^2-d^2)^2=16(s-a)(s-b)(s-c)(s-d)$$

3. Prove that $(b+c-a)^3+(c+a-b)^3+(a+b-c)^3$

$$-3(b+c-a)(c+a-b)(a+b-c)=4(a^3+b^3+c^3-3abc).$$

4. Show that, if $a+b+c=0$, then

$$\left(\frac{b-c}{a}+\frac{c-a}{b}+\frac{a-b}{c}\right)\left(\frac{a}{b-c}+\frac{b}{c-a}+\frac{c}{a-b}\right)=9.$$

5. If $x \quad a=y \quad b=z \quad c$, prove that

$$\frac{x^2+a^2}{x+a}+\frac{y^2+b^2}{y+b}+\frac{z^2+c^2}{z+c}=\frac{(x+y+z)^2+(a+b+c)^2}{x+y+z+a+b+c}.$$

6. Prove that, if $ax+by+cz=0$ and $\frac{a}{x}+\frac{b}{y}+\frac{c}{z}=0$, then will $ax^3+by^3+cz^3+(a+b+c)(y+z)(z+x)(x+y)=0$

7. Eliminate x, y, z from the equations

(i) $\left.\begin{aligned} ax+hy+gz=0 \\ hx+by+fz=0 \\ gx+fy+cz=0 \end{aligned}\right\}$, (ii) $\left.\begin{aligned} a(y+z)=x \\ b(z+x)=y \\ c(x+y)=z \end{aligned}\right\}$.

8. Eliminate l, m, n from the equations

$$\left.\begin{aligned} al=bm=cn, \\ l^2+m^2+n^2=1, \\ a^2l^3+b^2m^3+c^2n^3=a'^2l+b'^2m+c'^2n \end{aligned}\right\}$$

CHAPTER XXXIV

QUADRATIC EQUATIONS AND EXPRESSIONS

We have already explained in Chapter XX what quadratic equations are and how easy types of such equations can be solved We shall in the present article consider some examples of a harder type

I. Pure Quadratic Equations.

232. Such equations may, after suitable reduction and transformation, be expressed in the standard form

$$ax^2=c.$$

∴ The required solutions are

$$x=\pm\sqrt{\frac{c}{a}}.$$

The following examples will serve as illustrations

Example 1. If $\frac{35-2x}{9}+\frac{5x^2+7}{5x^2-7}=\frac{17-\frac{2}{3}x}{3}$, find x

By transposition, we have

$$\frac{5x^2+7}{5x^2-7}=\frac{51-2x}{9}-\frac{35-2x}{9}=\frac{16}{9};$$

$$\therefore \quad \frac{5x^2}{7}=\frac{16+9}{16-9}=\frac{25}{7} \text{ [componendo and dividendo.]}$$

$$\therefore \quad x^2=5, \qquad \therefore \quad x=\pm\sqrt{5}$$

Example 2. Solve $3\left(\frac{x^2-9}{x^2+3}\right)+4\left(\frac{22\frac{1}{2}+x^2}{x^2+9}\right)=7$

By transposing, we have

$$4\left(\frac{22\frac{1}{2}+x^2}{x^2+9}\right)-4=3-3\left(\frac{x^2-9}{x^2+3}\right),$$

or $$4\left\{\frac{22\frac{1}{2}+x^2}{x^2+9}-1\right\}=3\left\{1-\frac{x^2-9}{x^2+3}\right\},$$

or. $$4\times\frac{13\frac{1}{2}}{x^2+9}=3\times\frac{12}{x^2+3},$$

$\therefore$ $$\frac{3}{x^2+9}=\frac{2}{x^2+3}$$ [removing the factor 18 from both sides]

$$3x^2+9=2x^2+18,$$

$$x^2=9, \therefore x=\pm 3$$ [arguing as before]

Example 3. If $a+b=\frac{2a\sqrt{1+x^2}}{x+\sqrt{1+x^2}}$, find x

We have $(a+b)(x+\sqrt{1+x^2})=2a\sqrt{1+x^2}$,

$\therefore$ $$(a+b)x=(a-b)\sqrt{1+x^2},$$

or, $$(a+b)^2x^2=(a-b)^2(1+x^2).$$

$$x^2\{(a+b)^2-(a-b)^2\}=(a-b)^2,$$

or, $$x^2\,4ab=(a-b)^2;$$

$\therefore$ $$x^2=\frac{(a-b)^2}{4ab};$$

$\therefore$ $$x=\pm\frac{a-b}{2\sqrt{ab}}.$$

Example 4. If $\frac{1+\sqrt{x^2-1}}{1+2a\sqrt{x^2-1}}=\frac{\sqrt{x^2-1}-1}{x^2-2}$, find x

Put y for $\sqrt{x^2-1}$ and .. y^2-1 for x^2-2

Thus we have $\frac{1+y}{1+2ay}=\frac{y-1}{y^2-1}=\frac{1}{y+1}$,

Therefore $$(1+y)^2=1+2ay,$$

or, $$1+2y+y^2=1+2ay,$$

$$y+2=2a, \text{ or, } y=2(a-1),$$

i e $$\sqrt{x^2-1}=2(a-1),$$

$\therefore$ $$x^2-1=4(a-1)^2,$$

$\therefore$ $$x=\pm\sqrt{1+4(a-1)^2}.$$

Example 5. Solve $(a+x)^{\frac{1}{3}}+(a-x)^{\frac{1}{3}}=b$

Since $\{(a+x)^{\frac{1}{3}}+(a-x)^{\frac{1}{3}}\}^3$

$$=(a+x)+(a-x)+3(a^2-x^2)^{\frac{1}{3}}\{(a+x)^{\frac{1}{3}}+(a-x)^{\frac{1}{3}}\}$$

$$=2a+3(a^2-x^2)^{\frac{1}{3}}\times b\text{, [because }(a+x)^{\frac{1}{3}}+(a-x)^{\frac{1}{3}}=b\text{]}$$

therefore, cubing both sides of the equation, we get

$$2a+3(a^2-x^2)^{\frac{1}{3}}\times b=b^3,\quad\text{or,}\quad 3b(a^2-x^2)^{\frac{1}{3}}=b^3-2a,$$

$$\therefore\quad a^2-x^2=\left\{\frac{b^3-2a}{3b}\right\}^3;$$

$$\therefore\quad x^2=a^2-\left\{\frac{b^3-2a}{3b}\right\}^3;$$

$$\therefore\quad x=\pm\left\{a^2-\left(\frac{b^3-2a}{3b}\right)^3\right\}^{\frac{1}{2}}$$

Example 6. Solve $\dfrac{a+x}{a^{\frac{1}{2}}+(a+x)^{\frac{1}{2}}}+\dfrac{a-x}{a^{\frac{1}{2}}+(a-x)^{\frac{1}{2}}}=a^{\frac{1}{2}}.$

Since $(a+x)\{a^{\frac{1}{2}}+(a-x)^{\frac{1}{2}}\}=a^{\frac{1}{2}}(a+x)+(a+x)^{\frac{1}{2}}(a^2-x^2)^{\frac{1}{2}}$.

and $(a-x)\{a^{\frac{1}{2}}+(a+x)^{\frac{1}{2}}\}=a^{\frac{1}{2}}(a-x)+(a-x)^{\frac{1}{2}}(a^2-x^2)^{\frac{1}{2}}$

therefore, clearing the equation of fractions, we have

$$2a^{\frac{3}{2}}+(a^2-x^2)^{\frac{1}{2}}\{(a+x)^{\frac{1}{2}}+(a-x)^{\frac{1}{2}}\}$$

$$=a^{\frac{1}{2}}\{a^{\frac{1}{2}}+(a+x)^{\frac{1}{2}}\}\{a^{\frac{1}{2}}+(a-x)^{\frac{1}{2}}\}$$

$$=a^{\frac{1}{2}}[a+a^{\frac{1}{2}}\{(a+x)^{\frac{1}{2}}+(a-x)^{\frac{1}{2}}\}+(a^2-x^2)^{\frac{1}{2}}]$$

$$=a^{\frac{3}{2}}+a\{(a+x)^{\frac{1}{2}}+(a-x)^{\frac{1}{2}}\}+a^{\frac{1}{2}}(a^2-x^2)^{\frac{1}{2}}$$

Hence, removing $a^{\frac{3}{2}}$ from both sides and transposing, we get

$$a^{\frac{1}{2}}\{a-(a^2-x^2)^{\frac{1}{2}}\}=\{(a+x)^{\frac{1}{2}}+(a-x)^{\frac{1}{2}}\}\times\{a-(a^2-x^2)^{\frac{1}{2}}\}\quad(A)$$

whence $\qquad a^{\frac{1}{2}}=(a+x)^{\frac{1}{2}}+(a-x)^{\frac{1}{2}};$

squaring both sides, $a=2a+2(a^2-x^2)^{\frac{1}{2}}$,

$$\text{or,} \qquad -a=2(a^2-x^2)^{\frac{1}{2}},$$

$$\therefore \quad a^2=4(a^2-x^2),$$

$$\therefore \quad 4x^2=3a^2,$$

$$x=\pm\frac{a\sqrt{3}}{2}.$$

Note *It must be observed that the above equation admits of another solution which has been overlooked, for* $a-(a^2-x^2)^{\frac{1}{2}}$ *being a factor common to both sides of (A), if this be taken equal to zero, the given equation is evidently satisfied Hence* $(a^2-x^2)^{\frac{1}{2}}=a$, *or,* $x=0$ *is another solution The same remark applies to example 4, which the student will very easily see for himself*

EXERCISE 126.

Find the value of x in each of the following equations

1. $24x+\dfrac{7}{x}=\dfrac{169}{7}x$ **2.** $\dfrac{8x^2+10}{15}=7-\dfrac{50+4x^2}{25}$,

3. $\dfrac{14x^2+16}{21}-\dfrac{2x^2+8}{8x^2-11}=\dfrac{2x^2}{3}$,

4. $\dfrac{x+7}{x(x-7)}-\dfrac{x-7}{x(x+7)}=\dfrac{7}{x^2-73}$.

5. $\dfrac{x^3-1}{(x-1)^2}-\dfrac{x^3+1}{(x+1)^2}=6$

6. $\dfrac{1}{\sqrt{1-x}+1}+\dfrac{1}{\sqrt{1+x}-1}=\dfrac{1}{x}$.

[Rationalise both the terms of the left-hand side and then proceed]

7. $(1+x+x^2)^{\frac{1}{2}}=a-(1-x+x^2)^{\frac{1}{2}}$

8. $\dfrac{(x-a)(x-b)}{(x-ma)(x-mb)}=\dfrac{(x+a)(x+b)}{(x+ma)(x+mb)}$.

9. $\dfrac{ax+1+(a^2x^2-1)^{\frac{1}{2}}}{ax+1-(a^2x^2-1)^{\frac{1}{2}}}=\dfrac{b^2x}{2}$.

10. $(a+x)^{\frac{2}{3}}+(a-x)^{\frac{2}{3}}=3(a^2-x^2)^{\frac{1}{3}}$

11. $\dfrac{5x^2+17}{x^2-11}+\dfrac{14x^2-117}{2x^2-9}=12$

12. $\dfrac{x^2-1}{x^2-4}-\dfrac{x^2-5}{x^2-8}=\dfrac{x^2-2}{x^2-5}-\dfrac{x^2-6}{x^2-9}.$

13. $\{a+(a^2-x^2)^{\frac{1}{2}}\}^{\frac{1}{2}}+\{a-(a^2-x^2)^{\frac{1}{2}}\}^{\frac{1}{2}}$

$$=n\left\{\frac{a+x}{a+(a^2-x^2)^{\frac{1}{2}}}\right\}^{\frac{1}{2}}.$$

Since $a+(a^2-x^2)^{\frac{1}{2}}=\dfrac{(a+x)+(a-x)+2(a^2-x^2)^{\frac{1}{2}}}{2}$

$$=\frac{\{(a+x)^{\frac{1}{2}}+(a-x)^{\frac{1}{2}}\}^2}{2}$$

and similarly, $a-(a^2-x^2)^{\frac{1}{2}}=\dfrac{\{(a+x)^{\frac{1}{2}}-(a-x)^{\frac{1}{2}}\}^2}{2};$

∴ the left-hand side $=\dfrac{2(a+x)^{\frac{1}{2}}}{\sqrt{2}}=\sqrt{2}(a+x)^{\frac{1}{2}}$

[Hence, squaring both sides, &c.]

14. $\dfrac{(1+2x)^{\frac{1}{2}}-1}{(1-2x)^{\frac{1}{2}}+1}+\dfrac{(1-2x)^{\frac{1}{2}}+1}{(1+2x)^{\frac{1}{2}}-1}=2\sqrt{2}$

II. Solution of Adfected Quadratic Equations by factorisation.

233. Adfected quadratic equations can, by suitable transformation and reduction, be expressed in the standard form

$$ax^2+bx+c=0$$

If the left-hand side can be easily factorised, then by requating to zero either of these factors, we get a solution of the quadratic

The following are the illustrative examples.

Example 1. Solve $10(2x+3)(x-3)+(7x+3)^2=20(x+3)(x-1)$.

We have
$$\begin{aligned} 10(2x^2-3x-9)+(49x^2+42x+9)&=20(x^2+2x-3),\\ 49x^2-28x-21&=0,\\ \therefore\quad 7x^2-4x-3&=0,\\ \text{or,}\quad (7x^2-7x)+(3x-3)&=0.\\ \text{or,}\quad (7x+3)(x-1)&=0.\end{aligned}$$

Hence, either $\left.\begin{array}{l} 7x+3=0 \\ \text{and}\quad x=-\frac{3}{7} \end{array}\right\}$ or, $\left.\begin{array}{l} x-1=0 \\ \text{and}\ \therefore\ x=1 \end{array}\right\}$

Thus $-\frac{3}{7}$ and 1 are roots of the equations

Example 2. Solve $(7-4\sqrt{3})x^2+(2-\sqrt{3})x=2$.

Since $\quad 7-4\sqrt{3}=(2-\sqrt{3})^2$.

We have $\quad (2-\sqrt{3})^2x^2+(2-\sqrt{3})x=2$.

Hence, putting z for $(2-\sqrt{3})x$, we have
$$z^2+z-2=0,\quad \text{or,}\quad (z+2)(z-1)=0$$

Hence, either $\left.\begin{array}{l} z+2=0 \\ \text{and}\ \therefore\ z=-2 \end{array}\right\}$ or, $\left.\begin{array}{l} z-1=0 \\ \text{and}\ \therefore\ z=1 \end{array}\right\}$.

$$\left.\begin{aligned} \text{Thus,}\ x&=\frac{-2}{2-\sqrt{3}}=-2(2+\sqrt{3})\\ \text{or,}\ &=\frac{1}{2-\sqrt{3}}=2+\sqrt{3}\end{aligned}\right\}$$

Example 3. Solve $\sqrt{3x^2-7x-30}-\sqrt{2x^2-7x-5}=x-5$ (1)

we have *identically*

$$(3x^2-7x-30)-(2x^2-7x-5)=x^2-25 \quad . \quad (2)$$

i.e., this relation is true for every value of x, and hence it is also true for the particular value which x has in the proposed equation

From (1) and (2), by division,

$$\frac{(3x^2-7x-30)-(2x^2-7x-5)}{\sqrt{3x^2-7x-30}-\sqrt{2x^2-7x-5}}=\frac{x^2-25}{x-5},$$

or, $\quad \sqrt{3x^2-7x-30}+\sqrt{2x^2-7x-5}=x+5 \quad$ (3)

From (1) and (3), by addition,

$$2\sqrt{3x^2-7x-30}=2x,$$

$$3x^2-7x-30=x^2,$$

or, $$2x^2-7x-30=0,$$

or, $$(2x+5)(x-6)=0;$$

$$\therefore \quad x=-\tfrac{5}{2}, \text{ or, } 6$$

N B We might as well as have subtracted (1) from (3) and got the same result.

Example 4. Solve $\dfrac{1}{(x-b)(x-c)}+\dfrac{1}{(a+c)(a+b)}$

$$=\frac{1}{(a+c)(x-c)}+\frac{1}{(a+b)(x-b)}.$$

By transposition,

$$\frac{1}{x-c}\left\{\frac{1}{x-b}-\frac{1}{a+c}\right\}=\frac{1}{a+b}\left\{\frac{1}{x-b}-\frac{1}{a+c}\right\}.$$

Therefore, either $\dfrac{1}{x-b}-\dfrac{1}{a+c}=0,$

whence $\quad x=a+b+c,$ or, $\dfrac{1}{x-c}=\dfrac{1}{a+b},$

whence also $x=a+b+c$

Thus the equation has got two *equal roots*

Example 5. Solve $\dfrac{a+c(a+x)}{a+c(a-x)}+\dfrac{a+x}{x}=\dfrac{a}{a-2cx}.$

Since $\dfrac{a+c(a+x)}{a+c(a-x)}=\dfrac{a}{a+c(a-x)}+\dfrac{c(a+x)}{a+c(a-x)},$

we have by transposition,

$$(a+x)\left\{\frac{c}{a+c(a-x)}+\frac{1}{x}\right\}=a\left\{\frac{1}{a-2cx}-\frac{1}{a+c(a-x)}\right\}$$

or, $$(a+x)\ \frac{a(1+c)}{x\{a+c(a-x)\}}=a\ \frac{c(a+x)}{(a-2cx)\{a+c(a-x)\}},$$

or, $$\frac{(a+x)(1+c)}{x}=\frac{c(a+x)}{a-2cx}.$$

Hence, either $a+x=0$, and $\therefore$ $x=-a$,

or, $\dfrac{1+c}{x}=\dfrac{c}{a-2cx}$, whence $x=\dfrac{a(1+c)}{c(3+2c)}$.

Thus $-a$ and $\dfrac{a(1+c)}{c(3+2c)}$ are the roots of the equation

EXERCISE 127.

Solve the following equations·

1. $x^2+9x+18=6-4x$ **2.** $(x-2)(x+1)=208$.

3. $x^2+3a^2=4ax$ **4.** $\dfrac{x^2-b^2}{2}+ab=ax$.

5. $abx^2-(a+b)cx+c^2=0$ **6.** $12x^2+23ax-24a^2=0$.

7. $10(x-a)^2-41(x-a)b+21b^2=0$

8. $12(x-a)^2+28(x-a)(x-b)-5(x-b)^2=0$

9. $20x^2+x(a+2b)=30(a+b)^2+bx$

10. $\dfrac{3(10+x)}{95}-\dfrac{40}{3(10-x)}=\dfrac{x}{15}$.

11. $(a-b)x^2-(a+b)x+2b=0$

12. $\dfrac{x^2}{a^{\frac{1}{2}}+b^{\frac{1}{2}}}-\left(a^{\frac{1}{2}}-b^{\frac{1}{2}}\right)x=\dfrac{1}{(ab^2)^{-\frac{1}{2}}+(a^2b)^{-\frac{1}{2}}}$.

13. $\dfrac{2x(a-x)}{3a-2x}=\dfrac{a}{4}$. **14.** $\dfrac{16}{x^{\frac{1}{2}}}+\dfrac{x^{\frac{1}{2}}}{2}=\dfrac{6}{x^{\frac{1}{2}}}$.

15. $\dfrac{a}{x-a}+\dfrac{b}{x-b}=\dfrac{2c}{x-c}$. **16.** $\dfrac{a-\sqrt{2ax-x^2}}{a+\sqrt{2ax-x^2}}=\dfrac{x}{a-x}$.

17. $\sqrt{2x^2+5x-2}-\sqrt{2x^2+5x-9}=1$

18. $\sqrt{3x^2+7x-1}+\sqrt{3x^2+7x-10}=9$

19. $\sqrt{4x^2-7x+16}+\sqrt{4x^2-7x-1}=17$

20. $\sqrt{5x^2-6x+8}-\sqrt{5x^2-6x-7}=1$

234. If in the process of solving an adfected quadratic by factorisation, the factors are *not* easily obtained, any one of the following methods should be adopted

235. The ordinary method of solving an Adfected Quadratic. Bring the terms containing the unknown quantity to the left-hand side of the equation, and the

known quantities to the right-hand side; if the co-efficient of x^2 be negative, change the sign of every term of the equation and *then* divide every term by the co-efficient of x^2; thus the equation is reduced to the form $x^2+px=q$

Now add $\frac{p^2}{4}$ (i e, square of half the co-efficient of x) to both sides, on which the left-hand side becomes a complete square and we get $\left(x+\frac{p}{2}\right)^2=q+\frac{p^2}{4}$, whence $x+\frac{p}{2}=\pm\sqrt{q+\frac{p^2}{4}}$, and therefore $x=-\frac{p}{2}\pm\sqrt{q+\frac{p^2}{4}}$.

EXERCISE 128.

Solve the following equations

1. $70x-63=7x^2$

By transposition, we have $-7x^2+70x=63$

Since the co-efficient of x^2 is negative, changing the sign of every term, we get $7x^2-70x=-63$

Dividing both sides by 7, $x^2-10x=-9$

Now adding $(\frac{10}{2})^2$, or, 25 to both sides,

$$x^2-10x+25=25-9=16,$$

or, $(x-5)^2=16$.

Hence, $x-5=\pm4$ [because $x-5$ is a quantity of which the square is 16],

$$x=5+4, \text{ or, } 5-4,$$

i e $x=9$. or, 1.

2. $2x^2-11x+5=0$

By transposition, $2x^2-11x=-5$;

dividing both sides by 2, $x^2-\frac{11}{2}x=-\frac{5}{2}$

Adding $(\frac{11}{4})^2$ to both sides,

$$x^2-\tfrac{11}{2}x+(\tfrac{11}{4})^2=\tfrac{121}{16}-\tfrac{5}{2},$$

i e, $(x-\frac{11}{4})^2=\frac{81}{16}$,

$$\therefore x-\tfrac{11}{4}=\pm\tfrac{9}{4},$$

$$\therefore x=\tfrac{11}{4}\pm\tfrac{9}{4}=5, \text{ or, } \tfrac{1}{2}$$

3. $87-98x=30x-16x^2$

4. $17x^2-85x+216=65x-8x^2$.

5. $\dfrac{x^2+8}{11}=5x-x^2-5$.

6. $4(x^2-3\tfrac{3}{5}x)^2=10(x^2-4\tfrac{2}{5}x-6)+3(\tfrac{x}{5}-\tfrac{5}{3})$.

7. $4(5x^2-3\tfrac{7}{9}x)^2=5(x^2-7x+12)+\dfrac{8(x-9)}{9}$.

8. $2x+\ 02=2\ 45x-x^2$.

9. $4(x^2+23x-24)=29x^2-8x+1$

10. $(3x-1)(x-4)+(x-2)(2x-3)=4x(x-3)-5$.

The left-hand side $=(3x^2-13x+4)+(2x^2-7x+6)$
$=5x^2-20x+10$.

Hence, we have $5x^2-20x+10=4x^2-12x-5$,

$\therefore\ x^2-8x=-15$; [by transposition]

$\therefore\ x^2-8x+(4)^2=16-15$,

or, $(x-4)^2=1$,

$\therefore\ x-4=\pm 1$,

$\therefore\ x=4\pm 1=5$, or, 3

11. $(2x-5)(3x-7)-(x-1)(4x-5)=x^2-3(x+14)$.

12. $(3x-11)(x-2)+(2x-3)(x+4)+13x=10(2x-1)^2+12$.

13. $(x-\tfrac{1}{2})(x-\tfrac{1}{3})+(x-\tfrac{1}{3})(x-\tfrac{1}{4})=(x-\tfrac{1}{4})(x-\tfrac{1}{5})$.

14. $\dfrac{x}{15}+\dfrac{40}{3(10-x)}=\dfrac{3(10+x)}{95}$.

$\left[\text{By transposition, } \dfrac{40}{3(10-x)}=\dfrac{3(10+x)}{95}-\dfrac{x}{15}=\&c\right]$

15. $\dfrac{2x}{15}+\dfrac{3x-50}{3(10+x)}=\dfrac{12x+70}{190}$. **16.** $\dfrac{x+4}{x-4}+\dfrac{x-4}{x+4}=\dfrac{10}{3}$.

Subtracting 2 from both sides, we have

$$\left(\frac{x+4}{x-4}-1\right)+\left(\frac{x-4}{x+4}-1\right)=\frac{4}{3},$$

$$\text{or,}\quad \frac{8}{x-4}-\frac{8}{x+4}=\frac{4}{3},$$

$$\text{or,}\quad 2\left(\frac{1}{x-4}-\frac{1}{x+4}\right)=\frac{1}{3}$$

or, $\dfrac{2\times 8}{x^2-16}=\dfrac{1}{3}$;

$\therefore$ $x^2-16=48$,

$\therefore$ $x^2=64$,

$\therefore$ $x=\pm 8$

17. $\dfrac{x}{x+1}+\dfrac{x+1}{x}=\dfrac{13}{6}$. [Proceed as in the last example]

18. $\dfrac{x+3}{x+2}+\dfrac{x-3}{x-2}=\dfrac{2x-3}{x-1}$, [Proceeding as in example 16, we get $x^2-4x=0$, whence $(x-2)^2=4$; $x=2\pm 2=4$, or, 0]

19. $\dfrac{x-2}{x+2}+\dfrac{x+2}{x-2}=\dfrac{2(x+3)}{x-3}$. **20.** $\dfrac{x+2}{x-2}-\dfrac{x-2}{x+2}=\dfrac{5}{6}$.

$\left[\text{We have } \left(\dfrac{x+2}{x-2}-1\right)-\left(\dfrac{x-2}{x+2}-1\right)=\dfrac{5}{6}, \text{or, \&c \&c}\right]$

21. $\dfrac{x-6}{x-12}-\dfrac{x-12}{x-6}=\dfrac{5}{6}$. **22.** $\dfrac{2x-9}{2x-7}-\dfrac{2x-7}{2x-9}=\dfrac{7}{12}$.

23. $\dfrac{x+6}{x+7}-\dfrac{x+1}{x+2}=\dfrac{1}{3x+1}$. [C U Entr Paper, 1878]

24. $\dfrac{2x}{x-4}+\dfrac{2x-5}{x-3}=8\tfrac{1}{3}$.

$\left[\text{We have } \left(\dfrac{2x}{x-4}-2\right)+\left(\dfrac{2x-5}{x-3}-2\right)=4\tfrac{1}{3}\right]$

25. $\dfrac{x}{x+5}-\dfrac{11x}{11x-8}+\dfrac{7}{6-4x}=0$.

26. $\dfrac{1}{x+a}+\dfrac{1}{x+2a}+\dfrac{1}{x+3a}=\dfrac{3}{x}$.

$\left[\text{We have } \left(\dfrac{1}{x+a}-\dfrac{1}{x}\right)+\left(\dfrac{1}{x+2a}-\dfrac{1}{x}\right)+\left(\dfrac{1}{x+3a}-\dfrac{1}{x}\right)=0,\right.$

whence $\dfrac{1}{x+a}+\dfrac{2}{x+2a}+\dfrac{3}{x+3a}=0$,

or, $\dfrac{1}{x+a}+\dfrac{1}{x+3a}=-2\left(\dfrac{1}{x+3a}+\dfrac{1}{x+2a}\right)$,

whence $\left.\dfrac{x+2a}{x+a}=-\dfrac{2x+5a}{x+2a}; \therefore \text{\&c}\right]$

236. General expression for the roots of a quadratic.

N B The roots of any equation are those values of the unknown quantity that satisfy the equation

As every quadratic equation can be written in the form $ax^2+bx+c=0$ *(after suitable reduction if necessary) we must regard this equation as the general type of all quadratics Let us solve it*

By transposition, $ax^2+bx=-c$

Dividing both sides by a,

$$x^2+\frac{b}{a}x=-\frac{c}{a}.$$

Adding $\left(\frac{b}{2a}\right)^2$ to both sides,

$$x^2+\frac{b}{a}x+\left(\frac{b}{2a}\right)^2=\frac{b^2}{4a^2}-\frac{c}{a},$$

$$\text{or,}\quad \left(x+\frac{b}{2a}\right)^2=\frac{b^2-4ac}{4a^2},$$

$$\therefore\ x+\frac{b}{2a}=\pm\frac{\sqrt{b^2-4ac}}{2a},$$

$$\therefore\ x=\frac{-b\pm\sqrt{b^2-4ac}}{2a}.$$

Thus the roots of the quadratic $ax^2+bx+c=0$, are $\frac{-b+\sqrt{b^2-4ac}}{2a}$ and $\frac{-b-\sqrt{b^2-4ac}}{2a}$, and therefore we must regard the expression $\frac{-b\pm\sqrt{b^2-4ac}}{2a}$ as the *general expression* for the roots sought

By the application of the formula we can find out the roots of a quadratic equation without going through the process exalained in Art 235

Example 1. Write down the roots of $2x^2-13x+15=0$

Comparing this with the equation $ax^2+bx+c=0$, we have $a=2$, $b=-13$, $c=15$

Hence, the roots of the given equation are

$$=\frac{-(-13)+\sqrt{(-13)^2-4\times2\times15}}{2\times2}$$

$$=\frac{13\pm\sqrt{169-120}}{4}$$

$$=\frac{13\pm\sqrt{49}}{4}=\frac{13\pm7}{4},$$

That is, $x=5$, or, $\frac{3}{2}$

Example 2. Write down the roots of $-3x^2=11x-4$

Bringing all the terms to one side, we have

$$-3x^2-11x+4=0$$

Here $\quad a=-3,\ b=-11,\ c=4$

Hence, $\quad x=\frac{-(-11)\pm\sqrt{(-11)^2-4\times(-3)\times4}}{2\times(-3)}$

$$=\frac{11\pm\sqrt{121+48}}{-6}$$

$$=\frac{11\pm\sqrt{169}}{-6}$$

$$=\frac{11\pm13}{-6}=-4, \text{ or } \tfrac{1}{3}.$$

EXERCISE 129.

Write down the roots of the following equations :

1. $3x^2-17x+24=0$
2. $x^2+9x+20=0$
3. $6x^2=20-7x$
4. $-9x^2+25=6x-10.$
5. $8x^2=14x+15$
6. $-3x^2+20x=25$
7. $5+x-4x^2=0$

237. Sreedharacharyya's or (Hindu) Method of solving a quadratic. Reduce the equation to the form $px^2+qx=r$, multiply both sides of this by $4p$ (*i e*, by four times the co-efficient of x^2) and *then* add q^2 to both sides ; we thus get $4p^2x^2+4pqx+q^2=4pr+q^2$, the left-hand side of which is evidently a complete square, being equal to $(2px+q)^2$

Example 1. Solve $5x^2-17x+6=0$

By transposition, $\quad 5x^2-17x=-6$

Multiplying both sides by 4×5,

$$4\times(5x)^2-4\times(5x)\times17=-120$$

Adding $(17)^2$ to both sides, we have

$$4\times(5x)^2-4\times(5x)\times17+(17)^2=289-120,$$

$$\text{or,}\qquad (2\times5x-17)^2=169,$$

$$\therefore \quad 10x-17=\pm 13;$$

$$\therefore \quad x=\frac{17\pm 13}{10}=3, \text{ or, } \tfrac{2}{5}$$

Example 2. Solve $-8x^2+10x=3$

Multiplying both sides by $4\times(-8)$,

$$4\times 64x^2-4\times 8\times 10x=-96$$

Adding $(10)^2$ to both sides,

$$4\times 64x^2-4\times 8\times 10x+(10)^2=100-96,$$

$$\text{or,} \quad (2\times 8x-10)^2=4,$$

$$\therefore \quad 16x-10=\pm 2,$$

$$\therefore \quad x=\frac{10\pm 2}{16}=\frac{3}{4}, \text{ or, } \frac{1}{2}.$$

Example 3. $6x^2+23x=12x+10$

By transposition.

$$6x^2+11x=10.$$

Multiplying both sides by 4×6,

$$4\times(6x)^2+4\times(6x)\times 11=240$$

Adding $(11)^2$ to both sides

$$4\times(6x)^2+4\times(6x)\times 11+(11)^2=121+240,$$

$$\text{or,} \quad (2\times 6x+11)^2=361,$$

$$\therefore \quad 12x+11=\pm 19,$$

$$\therefore \quad x=\frac{-11\pm 19}{12}$$

$$=\tfrac{2}{3}, \text{ or, } -\tfrac{5}{2}$$

EXERCISE 130.

Solve the following equations by Sreedharacharyya's Method :

1. $2x^2+9x=18.$
2. $15x^2-28=x$
3. $16x^2+100x=3x^2+x+40$
4. $x^2+50x=102-15x-x^2.$
5. $17x^2+19x=1848.$
6. $2cx^2-acx=3(2x-a)$
7. $x^2+ax=ab(3x+a)-2x^2.$

238. Equations solved like Quadratics. Some equations. though not actually quadratics themselves, may by suitable substitutions, be expressed as quadratics, and thus solved

Example 1. Solve $x^4-10x^2+9=0$

Putting y for x^2, the equation is $y^2-10y+9=0$,

$$\text{or,}\quad (y-1)(x-9)=0$$

Hence, either $y-1=0$, or, $y-9=0$,

i e, $y=1$, or, 9,

i e, $x^2=1$, or, 9,

i e, $x=\pm 1$, or, ± 3

Example 2. Solve $\dfrac{25a^4}{x^2}+x^2=26a^2$

Multiplying both sides by x^2, $25a^4+x^4=26a^2x^2$,

$$\text{or,}\quad x^4-26a^2x^2+25a^4=0$$

Putting y for x^2, we have $y^2-26a^2y+25a^4=0$,

$$\text{or,}\quad (y-a^2)(y-25a^2)=0$$

Hence, either $y-a^2=0$, or, $y-25a^2=0$,

i e, $y=a^2$, or, $25a^2$,

i e, $x^2=a^2$, or, $25a^2$,

i e, $x=\pm a$, or, $\pm 5a$

Example 3. Solve $(x^2+3x)^2-(x^2+3x)-6=0.$

Putting y for x^2+3x, we have $y^2-y-6=0$,

$$\text{or,}\quad (y+2)(y-3)=0,$$

$\therefore$ Either (i) $y+2=0$, or, (ii) $y-3=0$

(i) If $y+2=0$, we have $x^2+3x+2=0$,

i e, $(x+1)(x+2)=0$,

i e, $x=-1$, or, -2

(ii) If $y-3=0$, we have $x^2+3x-3=0$

Solving the quadratic, $x=\dfrac{-3\pm\sqrt{21}}{2}$;

$$x=-1\quad -2, \text{ or, } \frac{-3\pm\sqrt{21}}{2}.$$

Example 4. Solve $(x+2)(x+3)(x+4)(x+5)=24(x^2+7x+7)$.

Re-arranging the factors on the left side, we have

$$\{(x+2)(x+5)\}\{(x+3)(x+4)\}=24(x^2+7x+7),$$

or, $(x^2+7x+10)(x^2+7x+12)=24(x^2+7x+7)$,

or, $(y+10)(y+12)=24(y+7)$

[putting y for x^2+7x]

or, $y^2+22y+120=24y+168$,

or, $y^2-2y-48=0$,

$\therefore$ $(y-8)(y+6)=0$.

Hence, either (i) $y-8=0$, or, (ii) $y+6=0$

(i) If $y-8=0$, we have $x^2+7x-8=0$.

or, $(x+8)(x-1)=0$,

$x+8=0$, or, $x-1=0$,

i.e., $x=-8$, or, 1.

(ii) If $y+6=0$, we have $x^2+7x+6=0$,

or, $(x+1)(x+6)=0$;

$\therefore$ $x+1=0$, or, $x+6=0$,

i.e., $x=-1$, or, -6

$x=-8, 1, -1$, or, -6

Example 5. Solve $3x^2-4x+\sqrt{3x^2-4x-6}=18$

Adding -6 to both sides, $3x^2-4x-6+\sqrt{3x^2-4x-6}=12$

Putting z for $\sqrt{3x^2-4-6}$,

the given equation reduces to $z^2+z=12$,

i.e., $z^2+z-12=0$,

or, $(z-3)(z+4)=0$,

$\therefore$ Either (i) $z=3$ or, (ii) $z=-4$

(i) If $z=3$, $\sqrt{3x^2-4x-6}=3$,

or, $3x^2-4x-6=9$,

or, $3x^2-4x-15=0$,

or, $(x-3)(3x+5)=0$;

$\therefore$ $x=3$, or, $-\frac{5}{3}$

(ii) If $z=-4$, $\sqrt{3x^2-4x-6}=-4$,

or, $3x^2-4x-6=16$,

or, $3x^2-4x-22=0$.

Solving the quadratic, $x=\frac{4\pm\sqrt{16+4.66}}{6}=\frac{2\pm\sqrt{70}}{3}$;

$\therefore \quad x=3, \ -\frac{5}{3}, \ \text{or}, \ \frac{2\pm\sqrt{70}}{3}.$

239. Equations of higher degrees solved by factorisation.

Example 1. Solve $x^3-7x+6=0$

By inspection $x-1$ is a factor of the left side.

Hence factorising the left side, the equation may be written as

$$(x-1)(x^2+x-6)=0,$$

or, $(x-1)(x-2)(x+3)=0$, [factorising the quadratic factor]

$\therefore$ Either $x-1=0$, or, $x-2=0$, or, $x+3=0$,

i.e., $x=1, 2$, or, -3

Example 2. Solve $x^3+1=0$

Here, we have $(x+1)(x^2-x+1)=0.$

. Either (i) $x+1=0$, or, (ii) $x^2-x+1=0$

(i) If $x+1=0, x=-1$

(ii) If $x^2-x+1=0$, solving the quadratic, we have

$$x=\frac{1\pm\sqrt{-3}}{2},$$

$$x=-1, \quad \text{or}, \ \frac{1\pm\sqrt{-3}}{2}.$$

Note *The square root of -3 is an impossible operation Such square roots are, however, frequently used in Algebra and are called imaginary quantities.*

Example 3. Solve $x^4+7x^3+8x^2+7x+1=0$

The left side of this equation is a *reciprocal expression* and may be put into factors, as in Art 143

Here, re-arranging the terms of the left side we have

$$(x^4+1)+7(x^3+x)+8x^2=0,$$

$$\text{or,} \quad (x^2+1)^2+7x(x^2+1)+6x^2=0,$$

or, $\{(x^2+1)+x\}\{(x^2+1)+6x\}=0$,

or, $(x^2+x+1)(x^2+6x+1)=0$.

$\therefore$ Either (i) $x^2+x+1=0$, or, (ii) $x^2+6x+1=0$.

(i) If $x^2+x+1=0$, solving we have

$$x=\frac{-1\pm\sqrt{-3}}{2}.$$

(ii) If $x^2+6x+1=0$, solving we have

$$x=\frac{-6\pm\sqrt{6^2-4}}{2}$$

$$=-3\pm\sqrt{8},$$

$$\therefore\quad x=\frac{-1\pm\sqrt{-3}}{2},\text{ or, }-3\pm\sqrt{8}$$

240. Exponential equations solved as a quadratic.

Example 1. Solve $5^{x-1}+5^{-x}=1\frac{1}{5}$.

Here, we have $\dfrac{5^x}{5}+\dfrac{1}{5^x}=\dfrac{6}{5}$,

or, $\dfrac{y}{5}+\dfrac{1}{y}=\dfrac{6}{5}$, [putting y for 5^x]

or, $y^2-6y+5=0$,

or, $(y-1)(y-5)=0$,

whence $y=1$, or, 5,

i e, $5^x=1$, or, 5,

i e, $5^x=5^0$, or, 5^1,

$\therefore$ $x=0$, or, 1

Example 2. Solve $2^{x-2}+2^{3-x}=3$

Here, we have $\dfrac{2^x}{2^2}+\dfrac{2^3}{2^x}=3$,

or, $\dfrac{y}{4}+\dfrac{8}{y}=3$, [putting y for 2^x]

or, $y^2-12y+32=0$,

or, $(y-4)(y-8)=0$;

$\therefore$ $y=4$, or, 8

i e, $2^x=4$, or, 8,

i e, $2^x=2^2$, or, 2^3,

$x=2$, or, 3.

EXERCISE 131.

Solve the equations

1. $x^3-6x^2+11x-6=0$
2. $x^3-4x^2+x+2=0$
3. $2x^3+5x^2-4x-3=0$
4. $x^3+5x^2-2x-6=0$
5. $x^3-4x^2+x+2=0$
6. $x^4-5x^3+6x^2-5x+1=0$.
7. $x^4-5x^3+14x^2-20x+16=0$
8. $x^4+8x^3+24x^2+32x-20=0$
9. $(x+2)(x+3)(x+4)(x+5)=360$
10. $(x-1)(x-2)(x+3)(x+4)+4=0$
11. $x^4-4x^3-x^2+10x+4=0$
12. $x^4-6x^3+15x^2-18x+5=0$
13. $2x^5-5x^4-3x^3+9x^2-x-2=0$,
14. $x^4-1=0$
15. $x^4-37x^2+36=0$.
16. $3^{x-2}+3^{3-x}=4$
17. $7^{x-3}+7^{2-x}=1\frac{1}{7}$
18. $2^x-2^{3-2x}=7(1-2^{1-x})$
19. $x^6-1=0$
20. $11^x+11^{-x}=121\frac{1}{121}$
21. $2x^2-5x-6\sqrt{2x^2-5x+3}=-8$
22. $9x-4x^2+\sqrt{4x^2-9x+11}=5$
23. $2(x^2-3x+1)^2+5(x^2-3x+1)+3=0$.
24. $(x+4)(x+1)+\sqrt{(x+5)(x-3)}=3x+31$
25. $10x^4-63x^3+52x^2+63x+10=0$

241. The Nature of Roots of a Quadratic.

If α, β denote the roots of the quadratic equation $ax^2+bx+c=0$, we have by Art 236,

$$\alpha=\frac{-b+\sqrt{b^2-4ac}}{2a} \text{ and } \beta=\frac{-b-\sqrt{b^2-4ac}}{2a}.$$

Three distinct cases do, therefore, arise according as the expression under the radical (b^2-4ac) is (1) zero, (2) positive and (3) negative

Case I. Equal Roots. If $b^2-4ac=0$, $\sqrt{b^2-4ac}=0$,

$$\therefore \quad \alpha=\frac{-b+0}{2a}=-\frac{b}{2a} \text{ and } \beta=\frac{-b-0}{2a}=-\frac{b}{2a}.$$

Hence, *the roots of $ax^2+bx+c=0$ are real and equal if* $b^2-4ac=0$

Example. Examine the roots of $4x^2-12x+9=0$

Here, $a=4$, $b=-12$ and $c=9$,

$$b^2-4ac=(-12)^2-4\cdot4\cdot9=144-144=0$$

Hence, the roots of $4x^2-12x+9=0$ are real and equal and are found to be $\frac{3}{2}, \frac{3}{2}$

Case II. Real and Unequal Roots. If b^2-4ac is a *positive* quantity, $\sqrt{b^2-4ac}$ is *real*

$\therefore$ α and β are *real* but *unequal*

Hence, *the roots of $ax^2+bx+c=0$ are real and unequal if b^2-4ac is positive*

(i) If b^2-4ac is a *perfect square*, $\sqrt{b^2-4ac}$ *is rational* and *real*

In this case, the roots are also *rational*, *real* and *unequal*

(ii) If b^2-4ac is *positive* but *not a perfect square*, $\sqrt{b^2-4ac}$ is real but irrational

Hence, the roots are also *real*, *irrational* and *unequal*

Example 1. The roots of $2x^2+7x-4=0$ are real and unequal as well as rational, since $7^2-4\cdot2(-4)=49+32=81$ is positive and a perfect square The roots are found to be $\frac{1}{2}$ and -4

Example 2. The roots of $2x^2-9x+8=0$ are real, unequal but irrational, since, $(-9)^2-4\cdot2\cdot8=81-64=17$ is positive but not a perfect square

Thus, the roots are $\dfrac{9\pm\sqrt{17}}{4}$.

Case III. Imaginary Roots. If b^2-4ac is negative, $\sqrt{b^2-4ac}$ = the square root of a negative quantity, which is an impossible operation Such square roots are however, frequently used in Algebra and are called **imaginary quantities.**

Hence, *if b^2-4ac is negative, the roots of $ax^2+bx+c=0$ are imaginary quantities*

Thus, the roots of $x^2-x+1=0$ are imaginary, since $(-1)^2-4\cdot1\cdot1=-3$ and is, therefore, a negative quantity

The roots are $\dfrac{1\pm\sqrt{(-1)^2-4\cdot1\cdot1}}{2}$, *i e*, $\dfrac{1\pm\sqrt{-3}}{2}$.

EXERCISE 132.

Examine the roots of the following equations

1. $3x^2+20x-19=0$. **2.** $3x^2-8x+9=0$

3. $x^2+5x+4=0$ **4.** $4x^2-12x+9=0$

5. $-3x^2-2x+6=0$ **6.** $-4x^2+5x-8=0$

7. $3x^2+7x+8=0$ **8.** $4x^2-8x+(4-a^2-b^2)=0$

9. $(a-b)x^2+2(a+b)x-(a-b)=0$

10. For what value of m will the equation $2x^2+8x+m=0$ have equal roots ?

11. If $4x^2-px+9=0$ has equal roots, find p

12. For what values of m will the equation $x^2-2(5+2m)x+3(7+10m)=0$ have equal roots ?

[By the condition of the problem

$$\{-2(5+2m)\}^2-4\cdot1\cdot3(7+10m)=0,$$

$$i\,e,\quad 4(5+2m)^2-4\cdot3(7+10m)=0,$$

$$\text{or,}\quad (25+20m+4m^2)-3(7+10m)=0,$$

$$\text{or,}\quad 2m^2-5m+2=0,$$

$$\text{or,}\quad (2m-1)(m-2)=0,$$

$$\therefore\quad m=\tfrac{1}{2},\text{ or, }2\ ]$$

13. Find the greatest and least values of $\dfrac{x^2+14x+9}{x^2+2x+3}$ for real values of x

[Let $\dfrac{x^2+14x+9}{x^2+2x+3}=m.$

Then $x^2+14x+9=m(x^2+2x+3)$,

or, $(1-m)x^2+2(7-m)x+3(3-m)=0$,

$\therefore\quad x=\dfrac{-2(7-m)+\sqrt{4(7-m)^2-4(1-m)3(3-m)}}{2(1-m)}.$

The expression under the radical sign

$=4(49-14m+m^2)-12(3-4m+m^2)$

$=-8(m^2+m-20)=-8(m-4)(m+5)$

Since x is real, the expression must be positive or zero,

i e, $-8(m-4)(m+5)$ must be positive or zero.

m cannot be *greater than* 4, but *may be equal to* 4 (since for *any* value of m greater than 4, say 5, the expression is negative).

Hence, the greatest value of the expression$=4$.

Similarly, *m cannot be* less than -5, but *may be equal to* (-5) (since for *any* value of m less than -5, say -6, the expression is negative)

Hence, the least value required$=-5$]

14. Prove that $\dfrac{x}{x^2-5x+9}$ must lie between 1 and $-\frac{1}{11}$ for all real values of x

15. Prove that the value of $\dfrac{x^2+8x+80}{2x+8}$ must not lie between -8 and 8, if x be real

[Let $\dfrac{x^2+8x+80}{2x+8}=m$ and proceed as in Ex 13]

16. If x be real, prove that $\dfrac{11x^2+12x+6}{x^2+4x+2}$ cannot lie between -5 and 3

17. If x be real, prove that $\dfrac{x^2-2x+21}{6x-14}$ cannot lie between 2 and $-\frac{10}{9}$

18. If x be real, the value of $\dfrac{(x-1)(x+3)}{(x-2)(x+4)}$ does not lie between $\frac{4}{9}$ and 1

242. A Quadratic Equation cannot have more than two roots.

Let $ax^2+bx+c=0$ be any quadratic equation To prove that it cannot have more than two roots

Proof. Since ax^2+bx+c

$$=a\left(x^2+\frac{b}{a}x+\frac{c}{a}\right)=a\left\{\left(x+\frac{b}{2a}\right)^2-\left(\frac{b^2}{4a^2}-\frac{c}{a}\right)\right\}$$

$$=a\left\{\left(x+\frac{b}{2a}\right)^2-\frac{(b^2-4ac)}{4a^2}\right\}$$

$$=a\left\{x+\frac{b}{2a}-\frac{\sqrt{b^2-4ac}}{2a}\right\}\left\{x+\frac{b}{2a}+\frac{\sqrt{b^2-4ac}}{2a}\right\}$$

[factorising]

$$=a(x-\alpha)(x-\beta),$$

$\left[\text{putting } \alpha \text{ for } \dfrac{-b+\sqrt{b^2-4ac}}{2a}\right.$

$\left.\text{and } \beta \text{ for } \dfrac{-b-\sqrt{b^2-4ac}}{2a}.\right]$

and since a is not zero, we have $ax^2+bx+c=0$ when and only when any one of the two factors $x-\alpha$, $x-\beta$ is zero,

i e. when and only when $x=\alpha$, or, β

Thus, the quadratic equation $ax^2+bx+c=0$ has got the two roots α and β and no more

243. *If a quadratic equation in x is satisfied by three different values of x, the equation will be satisfied by every value of x*

Let the quadratic equation $ax^2+bx+c=0$ be satisfied by three different values α, β, γ of x

$$a\alpha^2+b\alpha+c=0, \quad (1)$$

$$a\beta^2+b\beta+c=0, \quad (2)$$

$$\text{and} \quad a\gamma^2+b\gamma+c=0 \quad (3)$$

Subtracting (2) from (1), we have

$$a(\alpha^2-\beta^2)+b(\alpha-\beta)=0,$$

$$\text{or,} \quad (\alpha-\beta)\{a(\alpha+\beta)+b\}=0$$

Now $\because$ $\alpha-\beta$ is *not* zero (α and β being different),

$$\therefore \quad a(\alpha+\beta)+b=0 \qquad (4)$$

Similarly, from (1) and (3), $a(\alpha+\gamma)+b=0$ (5)

Hence, subtracting (5) from (4),

$$a(\beta-\gamma)=0$$

But $\beta-\gamma$ is *not* zero, (since β and γ are different)

$$\therefore \quad a=0$$

Hence from (4) $0(\alpha+\beta)+b=0$ *i e* $b=0$

Since, $a=0$, $b=0$, we have from (1). $c=0$

$ax^2+bx+c=0\,x^2+0\,x+0\,0=0$ *for every value of* x

244. Relations between Roots and Co-efficients of a quadratic.

If α and β be the roots of the quadratic $ax^2+bx+c=0$, to prove that

$$\alpha+\beta=-\frac{b}{a} \quad \text{and} \quad \alpha\beta=\frac{c}{a}.$$

Solving the equation as in Art 236, we have

$$\alpha=\frac{-b+\sqrt{b^2-4ac}}{2a}$$

and $$\beta=\frac{-b-\sqrt{b^2-4ac}}{2a}.$$

Hence, by addition, $\alpha+\beta=\dfrac{-2b}{2a}=-\dfrac{b}{a}$;

and by multiplication, $\alpha\beta=\dfrac{(-b+\sqrt{b^2-4ac})(-b-\sqrt{b^2-4ac})}{4a^2}$

$$=\frac{(-b)^2-(b^2-4ac)}{4a^2}=\frac{4ac}{4a^2}=\frac{c}{a}.$$

Since the equation $ax^2+bx+c=0$ can also be written as $x^2+\dfrac{b}{a}x+\dfrac{c}{a}=0$, we may express the result as follows

In a quadratic equation of the form $x^2+px+q=0$ (i e where *the co-efficient of* $x^2=1$ *and the terms are all on one side*,

(i) the sum of the roots $=-$the co-efficient of x

(ii) the product of the roots$=$the constant term

i e, the term independent of x

Example 1. If α, β denote the roots of the quadratic $x^2+6x+9=0$, prove that $\alpha+\beta=-6$ and $\alpha\beta=9$

Here, the co-efficient of $x^2=1$ and the terms are all on one side

Hence, we have $\alpha+\beta=-$the co-efficient of $x=-6$ and $\alpha\beta=$the constant term$=9$

Example 2. If α, β be the roots of $3x^2-17x+19=0$, prove that $\alpha+\beta=\frac{17}{3}$ and $\alpha\beta=\frac{19}{3}$

Re-writing the equation in the form $x^2+(-\frac{17}{3})x+\frac{19}{3}=0$, so that the *co-efficient of* $x^2=1$, and the *terms are all on one side*, we have $\alpha+\beta$

$=-$the co-efficient of $x=-(-\frac{17}{3})=\frac{17}{3}$

and $\alpha\beta=$the constant term$=\frac{19}{3}$

Example 3. If α, β are the roots of $x^2+px+q=0$, find (i) $\alpha-\beta$, (ii) $\alpha^3+\beta^3$, (iii) $\alpha^{-1}+\beta^{-1}$

We have $\alpha+\beta=-$the co-efficient of x in $x^2+px+q=-p$

and $\alpha\beta=$the constant term$=q$

(i) Since $(\alpha-\beta)=(\alpha+\beta)^2-4\alpha\beta=(-p)^2-4q=p^2-4q$,

$$\alpha-\beta=\pm\sqrt{p^2-4q}$$

(ii) $\alpha^3+\beta^3=(\alpha+\beta)^3-3\alpha\beta(\alpha+\beta)$

$$=(-p)^3-3q(-p)=-p^3+3pq$$

(iii) $\alpha^{-1}+\beta^{-1}=\dfrac{1}{\alpha}+\dfrac{1}{\beta}=\dfrac{\alpha+\beta}{\alpha\beta}=\dfrac{-p}{q}$.

245. Formation of Equations with given Roots.

Let α β be the given roots and let $x^2-px+q=0$ be the equation sought

$\alpha+\beta=-$(the co-efficient of x in $x^2-px+q=-(-p)=p$

and $\alpha\beta=$the constant term$=q$

Substituting for p and q in $x^2-px+q=0$

the required equation is $x^2-(\alpha+\beta)x+\alpha\beta=0$, (A)

or, $(x-\alpha)(x-\beta)=0$ (B)

Otherwise: The expression $(x-\alpha)(x-\beta)$ is zero if any one of its factors $x-\alpha$, $x-\beta$ is zero.

i e, if x has any one of the values α and β

Hence, *the equation whose roots are*, α, β is $(x-\alpha)(x-\beta)=0$

[Evidently the equation has no other roots, for, if the left-hand side is zero, one of its factors must be zero, so that x must have one of the values α or β]

Note *Similarly, the equation whose roots are* α, β, γ *is* $(x-\alpha)(x-\beta)(x-\gamma)=0$, *and so on*

Example 1. Form the quadratic whose roots are 4 and -5

By (B), the equation is $(x-4)\{x-(-5)\}=0$,

i e, $(x-4)(x+5)=0$,

or, $x^2+x-20=0$

Example 2. Form the quadratic whose roots are $3+\sqrt{5}$ and $3-\sqrt{5}$

Since $(3+\sqrt{5})+(3-\sqrt{5})=6$

and $(3+\sqrt{5})(3-\sqrt{5})=3^2-5=4$,

by (A), the equation sought is $x^2-6x+4=0$

Example 3. If α, β are the the roots of $ax^2+bx+c=0$, form the equation whose roots are $\dfrac{\alpha}{\beta}$ and $\dfrac{\beta}{\alpha}$.

By (A), the required equation is

$$x^2-\left(\frac{\alpha}{\beta}+\frac{\beta}{\alpha}\right)x+\frac{\alpha}{\beta}\cdot\frac{\beta}{\alpha}=0$$

or, $$x^2-\frac{\alpha^2+\beta^2}{\alpha\beta}x+1=0$$

Since, $\alpha+\beta=-\frac{b}{a}$ and $\alpha\beta=\frac{c}{a}$, we have

$$\frac{\alpha^2+\beta^2}{\alpha\beta}=\frac{(\alpha+\beta)^2-2\alpha\beta}{\alpha\beta}=\frac{\left(-\frac{b}{a}\right)^2-2\frac{c}{a}}{\frac{c}{a}}$$

$$=\frac{\frac{b^2}{a^2}-\frac{2c}{a}}{\frac{c}{a}}=\frac{b^2-2ac}{ac}.$$

Hence, the required equation is $x^2-\frac{b^2-2ac}{ac}x+1=0$

or, $acx^2-(b^2-2ac)x+ac=0$

Example 4. Form the quadratic whose roots are the reciprocals of the roots of the equation $x^2+3x+4=0$

Let α, β be the roots of $x^2+3x+4=0$

Find the equation whose roots are $\frac{1}{\alpha}$ and $\frac{1}{\beta}$.

By (A), the equation required is

$$x^2-\left(\frac{1}{\alpha}+\frac{1}{\beta}\right)x+\frac{1}{\alpha}\cdot\frac{1}{\beta}=0,$$

$$\text{or,}\qquad x^2-\frac{\alpha+\beta}{\alpha\beta}x+\frac{1}{\alpha\beta}=0 \qquad (1)$$

But since α, β are the roots of $x^2+3x+4=0$, we have $\alpha+\beta=-3$ and $\alpha\beta=4$

$$\frac{\alpha+\beta}{\alpha\beta}=\frac{-3}{4}, \text{ and } \frac{1}{\alpha\beta}=\frac{1}{4}.$$

Hence from (1), the required equation is $x^2-(-\frac{3}{4})x+\frac{1}{4}=0$,

or, $x^2+\frac{3}{4}x+\frac{1}{4}=0$,

or, $4x^2+3x+1=0$

246. Common Root of two Equations.

Let $\alpha=$ the common root of the equations $ax^2+bx+c=0$ and $a'x^2+b'x+c'=0$

We have $a\alpha^2+b\alpha+c=0$,

and $a'\alpha^2+b'\alpha+c'=0$

By cross multiplication, $\frac{\alpha^2}{bc'-b'c}=\frac{\alpha}{ca'-c'a}=\frac{1}{ab'-a'b}$;

$$\therefore \quad \alpha^2=\frac{bc'-b'c}{ab'-a'b} \text{ and } \alpha=\frac{ca'-c'a}{ab'-a'b}, \qquad (1)$$

$$\therefore \quad \frac{bc'-b'c}{ab'-a'b}=\left(\frac{ca'-c'a}{ab'-a'b}\right)^2,$$

$$\text{or,} \quad (ca'-c'a)^2=(bc'-b'c)(ab'-a'b) \qquad (2)$$

which is the equation that the equation shall have a common root From (1), the common root

$$=\frac{bc'-b'c}{ca'-c'a}, \text{ or, } \frac{ca'-c'a}{ab'-a'b}.$$

EXERCISE 133.

Form the equations whose roots are

1. 3 and 1 **2.** 5 and -7 **3.** 3 and $\frac{1}{3}$

4. (i) $3+\sqrt{5}$ and $3-\sqrt{5}$, (ii) $2a+\sqrt{b}$ and $2a-\sqrt{b}$.

5. Find the sum and product of the roots of

(i) $x^2-5x+6=0$, (ii) $x^2+9x-13=0$,

(iii) $-3x^2+20x+15=0$, (iv) $5x^2=7x+3$,

(v) $3x+1=-15x^2$.

6. If α and β are the roots of the equation $x^2+px+q=0$, form the equation whose roots are

(i) $\alpha^2+\alpha\beta$ and $\beta^2+\alpha\beta$;

[(i) $(\alpha^2+\alpha\beta)+(\beta^2+\alpha\beta)=\alpha^2+2\alpha\beta+\beta^2=(\alpha+\beta)^2=(-p)^2=p^2$

and $(\alpha^2+\alpha\beta)(\beta^2+\alpha\beta)=\alpha(\alpha+\beta)\beta(\alpha+\beta)=\alpha\beta(\alpha+\beta)^2=p^2q$,

since $\alpha+\beta=-p$ and $\alpha\beta=q$

Hence, the required equation is $x^2-p^2x+p^2q=0$]

(ii) $\alpha^2+\beta^2$ and $2\alpha\beta$, (iii) $\alpha^{-2}+\beta^{-2}$ and $\frac{2}{\alpha\beta}$;

(iv) $\alpha+\frac{1}{\beta}$ and $\beta+\frac{1}{\alpha}$.

7. If the equations $x^2+bx+ca=0$ and $x^2+cx+ab=0$ have a common root, their other roots will satisfy the equation $x^2+ax+bc=0$ [C U F A, 1879]

[Let α = the common root of the two equations

Then, $\alpha^2+b\alpha+ca=0$ (1)

and $\alpha^2+c\alpha+ab=0$

Subtracting $(b-c)\alpha+a(c-b)=0$

Dividing by $(b-c)$, $\alpha-a=0$,

i.e., $\alpha=a$

Since the product of the roots of the first equation $=ca$, and one of these roots $=a$,

the other root of the 1st equation $=\dfrac{ca}{a}=c$

Similarly, the remaining root of the 2nd equation $=\dfrac{ab}{a}=b$

Hence, the required equation has the roots b and c, and is, therefore, $x^2-(b+c)x+bc=0$ (2)

Since $\alpha=a$, we have from (1), $a^2+ba+ca=0$

i e, $a(a+b+c)=0$

or, $a+b+c=0$

from (2), we have $x^2+ax+bc=0$ ($b+c=-a$)]

8. If x be real, show that $\dfrac{m^2}{1+x}-\dfrac{n^2}{1-x}$ can have any real value [M U 1883]

[Let the given expression $=y$

$$\frac{m^2(1-x)-n^2(1+x)}{1-x^2}=y,$$

or, $yx^2-(m^2+n^2)x-(y-m^2+n^2)=0$

Solving, $x=\dfrac{m^2+n^2\pm\sqrt{(m^2+n^2)^2+4y(y-m^2+n^2)}}{2y}$.

Since x is real, the expression under the radical sign must be positive,

or, $(m^2+n^2)^2-4y(m^2-n^2)+4y^2$ is positive,

or, $(m^2-n^2)^2-4y(m^2-n^2)+4y^2+4m^2n^2$ is positive

or, $(m^2-n^2-2y)^2+4m^2n^2$ must be positive

This condition can evidently be satisfied by giving any real value to y, i e, to the expression]

9. If the equations $x^2+px+q=0$ and $x^2+p'x+q'=0$ have a common root, show that it must be either $\dfrac{pq'-p'q}{q-q'}$, or, $\dfrac{q-q'}{p'-p}$.

10. Form the equation whose roots are reciprocals of the roots of (i) $3x^2+8x+91=0$, (ii) $ax^2+bx+c=0$.

11. If one root of the equation $ax^2+bx+c=0$, be the square of the other, prove that $b^3+a^2c+ac^2=3abc$.

12. If $ax^2+bx+c=a'x^2+b'x+c'$ when $x=183$, 281 and 397 respectively, prove that $a=a'$, $b=b'$ and $c=c'$

[$(ax^2+bx+c)-(a'x^2+b'x+c')=0$,

i e, $(a-a')x^2+(b-b')x+(c-c')=0$ for three *distinct* values of x

. By Art 243, $a-a'=0$, $b-b'=0$ and $c-c'=0$]

13. Find a, b, c, if $(a-12)x^2+(b-31)x=181-c$ for any value of x

14. Find k, if the roots of $5x^2+7kx+3=0$ be the reciprocals of the roots of $3x^2+(8-k)x+5=0$

15. Find a and k, if the roots of $3x^2+2kx+k+2=0$ be the reciprocals of the roots of $2ax^2+(k+a)x+3=0$

CHAPTER XXXV

EQUATIONAL PROBLEMS

247. What are eggs a dozen when two more in a shilling's worth lowers the price one penny per dozen?

Let x = the number of eggs we get for a shilling

Then the price of each egg $=\frac{12}{x}$ pence.

and $\therefore$ the price of a dozen $=\frac{144}{x}$ pence . (1)

If two more were obtained for a shilling i.e if $(x+2)$ eggs were worth a shilling the price of a dozen would for a similar reason be $\frac{144}{x+2}$ pence

But by the condition of the problem, the latter price is one penny less than the former price hence

$$\frac{144}{x+2}=\frac{144}{x}-1$$

$$x^2+2x=288$$

$$x^2+2x+1=289$$

$$\therefore \quad x+1=17$$

$$x=16$$

Hence from (1) the price per dozen $=9d$

248. Find two numbers whose difference multiplied by the difference of their squares $=160$; and whose sum multiplied by the sum of their squares gives the number 580

Let $x+y$ and $x-y$ be the numbers

Then by the 1st condition of the problem,

$$2y\,(4xy)=160$$

$$\text{or,} \quad xy^2=20$$

By the 2nd condition of the problem,

$$2x\{2(x^2+y^2)\}=580$$

or $$x(x^2+y^2)=145 \qquad \ldots \quad (2)$$

From (1) and (2) by subtraction,

$$x^3=125=5^3,$$

$$\therefore \quad x=5$$

Hence from (1), $xy^2=5y^2=20$

i e $\quad y^2=4,$

$\therefore \quad y=2,$

$x=5$ and $y=2$

Hence the required numbers are 7 and 3

249. *A* sets off from London to York and *B* at the same time from York to London, and they travel uniformly, *A* reaches York 16 hours and *B* reaches London 36 hours, after they have met on the road Find in what time each has performed the journey

Let L, Y represent London and York respectively, and M the place where the travellers meet Let m, n be the measures of LM, MY respectively in miles

Now since A travels n miles (i e, from M to Y) in 16 hours he travels 1 mile in $\frac{16}{n}$ hours and m miles in $\frac{16}{n}\cdot m$ hours hence the time in which A travelled from L to M

$$=\frac{16}{n}\cdot m \text{ hours}$$

Similarly the time in which B travelled from Y to M

$$=\frac{36}{m}\cdot n \text{ hours}$$

Now, since they started at the same instant, the time in which A travelled from L to M is evidently equal to the time in which B travelled from Y to M

$$\frac{16}{n}\cdot m=\frac{36}{m}\cdot n,$$

whence $$\frac{m}{n}=\frac{3}{2}.$$

Hence, the time in which A performed the journey

$$=\left(\frac{16}{n}\cdot m+16\right) \text{hours}=40 \text{ hours},$$

and the time in which B performed the journey

$$=\left(\frac{36}{m}\cdot n+36\right) \text{hours}=60 \text{ hours}$$

250. A fraudulent tradesman contrives to employ his *false* balance both in buying and selling a certain article, thereby gaining 11 per cent more on his outlay than he would gain, were the balance *true* If however the scale pans, in which the article is weighed when bought and sold respectively, were interchanged, he would neither gain nor lose by the transaction Determine the legitimate gain per cent on the article

[In a *false* balance if any weight be placed on one of the scale pans, the weight to be put on the other pan in order to make the beam horizontal will be *different* For instance, if in buying rice a five-seer counterpoise be put on the pan, the quantity of rice put on the other will be either more or less than 5 seers Suppose when the five-seer counterpoise is put on the scale pan A, we are required to put on the pan B, a quantity of rice whose real weight is greater than 5 seers, but whatever may be its real weight, as its weight now is supposed to be equal to the weight of the counterpoise, we *take it to be* 5 seers Thus we take for 5 seers what is really more than 5 seers Hence, if the merchant contrives to put the counterpoise on A and the article bought on B, he will evidently take away more of the article than he is supposed to do, let the supposed weight of the article, so bought, be w lbs, if then W lbs be the *real* weight of the article, w is less than W Again in selling the article if he puts the counterpoise on B and the article on A and if W' be the weight of the counterpoise, then W' is greater than W By this contrivance then the merchant buys W lbs of the article at the price of w lbs and sells away these W lbs again at the price of W' lbs Hence, in such a transaction the merchant's gain is two-fold, he buys more of the article than he pays for and the whole quantity thus bought he sells away at the price of a still greater quantity]

Let w and W' be the *apparent* weights of the article when bought and sold respectively

Then evidently w is less, and W' greater, than the true weight

Let p = prime cost of unit of weight,

x = the legitimate gain per cent

Then the selling price of a unit of weight

$$= p + x \textit{ hundredths of } p = p\left(1+\frac{x}{100}\right).$$

Hence, the price paid by the merchant in buying the article, *i e*. his outlay $= wp$, and the price realised by selling it $= W'p.\left(1+\frac{x}{100}\right)$.

by the condition of the problem,

$$W'p\left(1+\frac{x}{100}\right) = wp + (x+11) \textit{ hundredths of } wp$$

$$= wp\left(1+\frac{x+11}{100}\right). \qquad (1)$$

If the scale pans were interchanged, the cost of buying the article would be $W'p$ and the price realised by sale, $wp\left(1+\frac{x}{100}\right)$; hence by the 2nd condition of the problem,

$$wp\left(1+\frac{x}{100}\right) = W'p \qquad (2)$$

From (1) and (2),

$$\frac{1+\frac{x+11}{100}}{1+\frac{x}{100}} = 1+\frac{x}{100},$$

or, $$\left(1+\frac{x}{100}\right)^2 = 1+\frac{x+11}{100},$$

or, $$\left(\frac{x}{100}\right)^2 + \frac{x}{100} + \frac{1}{4} = \frac{11}{100} + \frac{1}{4} = \frac{36}{100},$$

$$\therefore \quad \frac{x}{100}=\frac{6}{10}-\frac{1}{2}=\frac{1}{10};$$

$$x=10,$$

i e, the legitimate gain is 10 per cent

251. A body of men were formed into a hollow square three deep, when it was observed that with the addition of 25 to their number, a solid square might be formed, of which the number of men in each side would be greater by 22 than the square root of the number of men in each side of the hollow square Required the number of men in the hollow square

[A number of men are said to be arranged in a *solid* square when they are arranged in parallel rows and the number of rows is equal to the number of men in each row The following diagram, in which A_1, B_1, &c represent men, will clearly illustrate the matter

$$\begin{array}{cccccccc}
A_1 & B_1 & C_1 & D_1 & E_1 & F_1 & G_1 & H_1 \\
A_2 & B_2 & C_2 & D_2 & E_2 & F_2 & G_2 & H_2 \\
A_3 & B_3 & C_3 & D_3 & E_3 & F_3 & G_3 & H_3 \\
A_4 & B_4 & C_4 & D_4 & E_4 & F_4 & G_4 & H_4 \\
A_5 & B_5 & C_5 & D_5 & E_5 & F_5 & G_5 & H_5 \\
A_6 & B_6 & C_6 & D_6 & E_6 & F_6 & G_6 & H_6 \\
A_7 & B_7 & C_7 & D_7 & E_7 & F_7 & G_7 & H_7 \\
A_8 & B_8 & C_8 & D_8 & E_8 & F_8 & G_8 & H_8
\end{array}$$

The above diagram represents an arrangement in which there are 8 rows, each containing 8 men This is a *solid*

square If the square $C_3F_3F_6C_6$ be removed from inside, the remainder will be a *hollow* square *two deep* having 8 men in each side, if, however the square $D_4E_4E_5D_5$ be removed, the remainder will be a *hollow* square *three deep*

Hence, the number of men in a *hollow* square *two deep* having x men in each side $=x^2-(x-4)^2$; in one *three deep* $=x^2-(x-6)^2$, and so on, thus the number of men in a hollow square n deep having x men in each side $=x^2-(x-2n)^2$]

Let x = the number of men in a side of the hollow square, then the whole number of men $=x^2-(x-6)^2$ (1)

Hence, by the 2nd condition of the problem,

$$x^2-(x-6)^2+25=(x^{\frac{1}{2}}+22)^2,$$

or $$12x-11=x+44x^{\frac{1}{2}}+484;$$

$$11x-44x^{\frac{1}{2}}=495,$$

or, $$x-4x^{\frac{1}{2}}=45,$$

$$x-4x^{\frac{1}{2}}+4=49,$$

$$\therefore\quad x^{\frac{1}{2}}-2=7,$$

whence $$x=81$$

Hence, from (1), the whole number of men

$$=81^2-75^2$$
$$=156\times 6=936$$

252. *K* engages to play a game of chess with *B* on the following conditions that *B* should name a certain number and put into *K*'s possession twenty-four rupees together with as many rupees as equal to the square of this number and that at the conclusion of the game *K* should return to *B* only a number of rupees equal to eight times the number named What number could *B* name with the greatest advantage possible to himself?

Let x = the number which *B* should name, then he has to deposit with *K*, $(24+x^2)$ rupees and get back at the end of the game only $8x$ rupees,

hence B has altogether to lose $(x^2+24-8x)$ rupees ,

∴ x must be such that this loss may be as small as possible

Now, since $x^2-8x+24=(x-4)^2+8$ which is always greater than 8 except when $x=4$, the loss will for all values of x be greater than Rs 8 except when x has this value

Hence, in order that the loss may be a minimum B should name the number 4

253. With the object of examining a student of the 1 st year as regards his progress in Algebra, I undertake to engage in a certain contract with him, which is as follows he is to give me a certain number of books, each worth as many rupees as the number of books and to get from me in return six times as many rupees as any of those books is worth and also 21 rupees more How many books should he bring me with the greatest possible advantage to himself ?

Let x=the number of books that the student brings me , then, since the price of each book is x rupees evidently I get x^2 rupees from him , and in return I give him $(6x+21)$ rupees

Hence, his gain (or loss as the case may be)

$$=(21+6x-x^2) \text{ rupees}$$

Now, $$21+6x-x^2=21-(x^2-6x)$$
$$=30-(x^2-6x+9)$$
$$=30-(x-3)^2$$

Evidently therefore, the student is a loser if $x-3$ be greater than 5, i e if x be greater than 8; and he is a gainer if x be 8 or less than 8

But not only should the student be a gainer but his gain must be the greatest possible, which evidently is the case when $(x-3)^2$ is the least possible, i e, when $x=3$

Hence, the student should bring me only three books

254. Rama, Lakshmana and Bharata went to visit a Rishi and brought their wives with them The Rishi knew the wive's names to be Urmila, Mandavi and Sita, but forgot which was the wife of each hero They told the Rishi

that they had given presents to Pandits, and that each of the six had rewarded as many Pandits, as he or she had given gold mudras to each Pandit Rama had rewarded 23 more Pandits than Urmila, and Lakshmana had rewarded 11 Pandits more than Mandavi, likewise each hero had given away 63 gold mudras more than his wife The Rishi having thought on what they said, dismissed them with his blessing, naming correctly the wife of each hero From the conditions given, do you also find out the names of the wives

Let x = the number of Pandits rewarded by any hero,

and y = the number of Pandits rewarded by his wife ,

then the number of gold mudras given away by the hero $= x^2$;

and the number of gold mudras given away by his wife $= y^2$

Hence, by the last condition of the problem, we have

$$x^2 - y^2 = 63,$$

$$\text{or,} \quad (x+y)(x-y) = 63$$

But $\quad 63 = 63 \times 1$, or, 21×3, or, 9×7 ,

hence, since $x+y$ and $x-y$ are positive integers, and $x+y$ is necessarily greater than $x-y$, we get the following three pairs of values for $x+y$, and $x-y$ and *no other* ,

$$(1) \left.\begin{aligned} x+y&=63 \\ x-y&=1 \end{aligned}\right\}, \quad (2) \left.\begin{aligned} x+y&=21 \\ x-y&=3 \end{aligned}\right\} \quad (3) \left.\begin{aligned} x+y&=9 \\ x-y&=7 \end{aligned}\right\}$$

Hence, we have the following three pairs of values for x and y .

$$(1) \left.\begin{aligned} x&=32 \\ y&=31 \end{aligned}\right\}, \quad (2) \left.\begin{aligned} x&=12 \\ y&=9 \end{aligned}\right\}, \quad (3) \left.\begin{aligned} x&=8 \\ y&=1 \end{aligned}\right\} \qquad (A)$$

i e the wife of the hero who rewarded 32 Pandits, rewarded 31 Pandits ;

the wife of the hero who rewarded 12 Pandits, rewarded 9 Pandits ; (α)

and the wife of the hero who rewarded 8 Pandits, rewarded only one Pandit (β)

Now let us find out the names of the wives from the other conditions of the problem

The number of Pandits rewarded by Rama may be 32, 12 or 8; but since he is known to have rewarded 23 *more* Pandits than somebody else, the number of Pandits rewarded by him *must be* 32

The number of Pandits rewarded by Lakshmana may then be either 12 or 8, but as he is known to have rewarded 11 *more* Pandits than somebody else, the number of Pandits rewarded by him *must be* 12 .. (*a*)

Hence, the number of Pandits rewarded by Bharata *must be* 8 . . .. . (*b*)

Again, since the number of Pandits rewarded by Urmila is 23 less than the number rewarded by Rama, it *must be* 9, hence by (*a*) and (*a*), Urmila is the wife of Lakshmana,

also, since the number of Pandits rewarded by Mandavi is 11 less than the number rewarded by Lakshmana, it *must* be 1, and by (*β*) and (*b*) Mandavi as the wife of Bharata; evidently ∙ Sita is the wife of Rama

Thus we have

Rama }	Lakshmana }	Bharata }
Sita }	Urmila }	Mandavi }

EXERCISE 134.

1. A person bought a certain number of oxen for £80, if he had bought 4 more for the same sum, each ox would have cost £1 less, find the number of oxen and the price of each

2. A gentleman sends a lad into the market to buy a shilling's worth of oranges The lad having eaten a couple, the gentleman pays at the rate of a penny for fifteen more than the market price, how many did the gentleman get for his shilling?

3. The plate of a looking glass is 18 inches by 12, and is to be framed with a frame of equal width, whose area is to be equal to that of the glass Required the width of the frame

4. *A* and *B* lay out some money on speculation *A* disposes of his bargain for £11, and gains as much *per cent* as *B* lays out, *B*'s gain is £36, and it appears that *A* gains four times as much *per cent* as *B*. Required the capital of each

5. A boat's crew row $3\frac{1}{2}$ miles down a river and back again in 1 hour and 40 minutes Supposing the river to have a current of 2 miles per hour, find the rate at which the crew would row in still water

6. What two numbers are those whose sum multiplied by the greater is 204, and whose difference multiplied by the less is 35?

7. What two numbers are those whose sum added to the sum of their squares is 42 and whose product is 15?

8. *A* and *B* distribute £60 each among a certain number of persons *A* relieves 40 persons more than *B* does, and *B* gives to each 5*s* more than *A* How many persons did *A* and *B* respectively relieve?

9. The product of two numbers added to their sum is 23, and five times their sum taken from the sum of their squares leaves 8, required the numbers

10. A horse dealer buys a horse, and pays a certain sum for it, he afterwards sells it again for Rs 171, and gains exactly as much per cent as the horse had cost him How much did he pay for the horse?

11. The small wheel of a bicycle makes 135 revolutions more than the large wheel in a distance of 260 yards, if the circumference of each were one foot more the small wheel would make 27 revolutions more than the large wheel in a distance of 70 yards, find the circumference of each wheel.

12. By lowering the price of apples and selling them one penny a dozen cheaper, an apple-woman finds that she can sell 60 more than she used to do for 5*s* At what price per dozen did she sell them at first?

13. There is a number between 10 and 100, when multiplied by the digit on the left the product is 280, if the sum of the digits be multiplied by the same digit the product is 55, required the number

14. *A* and *B* are two stations 300 miles apart Two trains start simultaneously from *A* and *B*, each to the opposite station The train from *A* reaches *B* nine hours, the train from *B* reaches *A* four hours, after they meet, find the rate at which each train travels

15. By selling a horse for £24, I lose as much per cent. as it costs me What was the prime cost of it?

16. Find three numbers, such that if the first be multiplied by the sum of the second and third, the second by the sum of the first and the third and the third by the sum of the first and the second, the products shall be 408, 480 and 504 respectively

17. There are two square buildings that are paved with stones, a foot square each The side of one building exceeds that of the other by 12 feet, and both their pavements taken together contain 2120 stones What are the lengths of them separately?

18. There are three numbers, the difference of whose differences is 5, their sum is 44, and continued product 1950, find the numbers

19. A train A starts to go from P to Q, two stations 240 miles apart and travels uniformly An hour later, another train B starts from P, and after travelling for 2 hours, comes to a point that A had passed 45 minutes previously The pace of B is now increased by 5 miles an hour and it overtakes A just on entering Q Find the rates at which they started

20. A square court-yard has a rectangular gravel walk round it inside The side of the court wants 2 yards of being 6 times the breadth of the gravel walk; and the number of square-yards in the walk exceeds the number of yards in the periphery of the court by 92 Required the area of the court

21. Divide the number 26 into three such parts that their squares may have equal differences, and that the sum of those squares may be 300

22. The number of soldiers present at a review is such that they could all be formed into a solid square and also could be formed into four hollow squares each 4 deep and each containing 24 more men in the front rank than when formed into a solid square, find the whole number

23. A and B run a race round a two-mile course In the first heat B reaches the winning post 2 minutes before A In the second heat A increases his speed 2 miles an hour, and B diminishes his by the same quantity, and A then reaches the winning post 2 minutes before B Find at what rate each ran in the first heat

24. From a vessel of wine containing a gallons, b gallons are drawn off and the vessel is filled up with water

Find the quantity of wine remaining in the vessel when this has been repeated 4 times

25. A wall was built round a rectangular court to a certain height Now the length of one side of the court was two yards less, whilst three times the length of the other was 25 yards greater, than 8 times the height of the wall, and the number of square yards in the court was greater than the number in the wall by 178 Required the dimensions of the court, and the height of the wall

26. A person bought a number of £20 railway shares when they were at a certain rate per cent discount for £1,500, and afterwards when they were at the same rate per cent. premium sold them all but 60 for £1,000 How many did he buy and what did he give for each of them?

27. The sum of 4 numbers is 44, the sum of the product of the 1st and 2nd and 3rd and 4th is 250; of the 1st and 3rd, and 2nd and 4th is 234, and of the 1st and 4th, and 2nd and 3rd is 225 Find them

28. To complete a certain work A requires m times as long a time as B and C together; B requires n times as long as A and C together; and C requires p times as long as A and B together Compare the times in which each would do it and prove that,

$$\frac{1}{m+1}+\frac{1}{n+1}+\frac{1}{p+1}=1.$$

29. In a certain village there lived in the year 1872 a number of families each consisting of as many members as there were families Ten years afterwards it was found that during this interval there were 670 births in the village and that on the average 50 lives were lost per family. Prove that the number of persons, living in the village at the time of this calculation, could not be less than 45, and if this number be actually 45, find out the number of souls that lived in the village in the year 1872

30. Suppose you agree to give me out of your landed property a square plot of ground and receive in exchange a circular plot of land whose area is 76 square feet and also a rectangular plot, one of whose sides is 36 feet and the other is equal to a side of the piece of land you give me What must be the area of the plot you give me, so that you can profit most by the exchange.

CHAPTER XXXVI

GRAPHS OF QUADRATIC EQUATIONS AND EXPRESSSIONS AND THEIR APPLICATIONS

255. The graphs of $XY=0$, X and Y being expressions of the first degree in x and y.

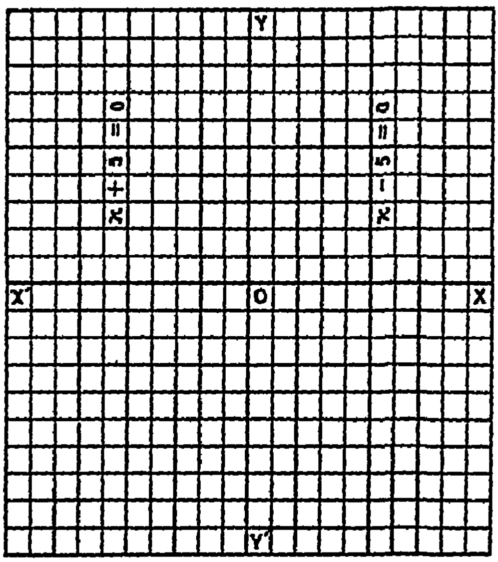
Example 1. Draw the graph of the equation

$$x^2=25.$$

The equation $x^2=25$ may be written as

$$\left.\begin{array}{r} x^2-25=0, \\ \text{or,}\quad (x-5)(x+5)=0 \end{array}\right\}$$

Evidently, the given equation is satisfied (i) by all those points which satisfy the equation $x-5=0$, (ii) by all those points which satisfy the equation $x+5=0$

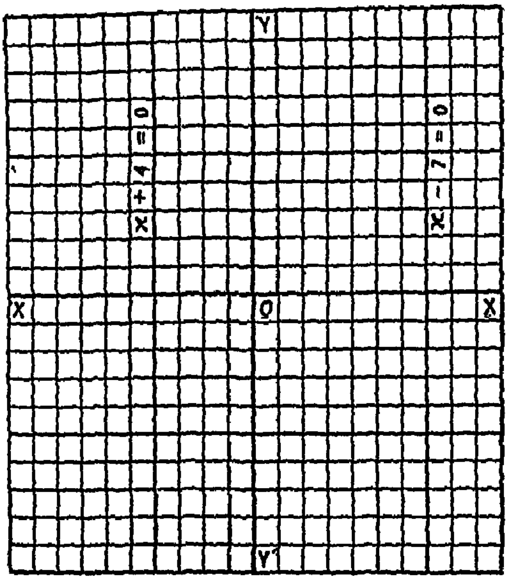


Hence, **the required graph consists of two straight lines,** one being the graph of the equation $x-5=0$ and the other being the graph of the equation $x+5=0$, as shown in the diagram.

Example 2. Draw the graph of the equation $x^2-3x-28=0$.

Factorising the left-side of the equation, we have

$$(x-7)(x+4)=0$$



Hence, proceeding as in example 1, we notice that **the required graph consists of two straight lines,** one being the graph of the equation $x-7=0$ and the other being the graph of $x+4=0$, as shown in the adjoining diagram

Example 3. Draw the graph of the equation $y^2=4x^2$

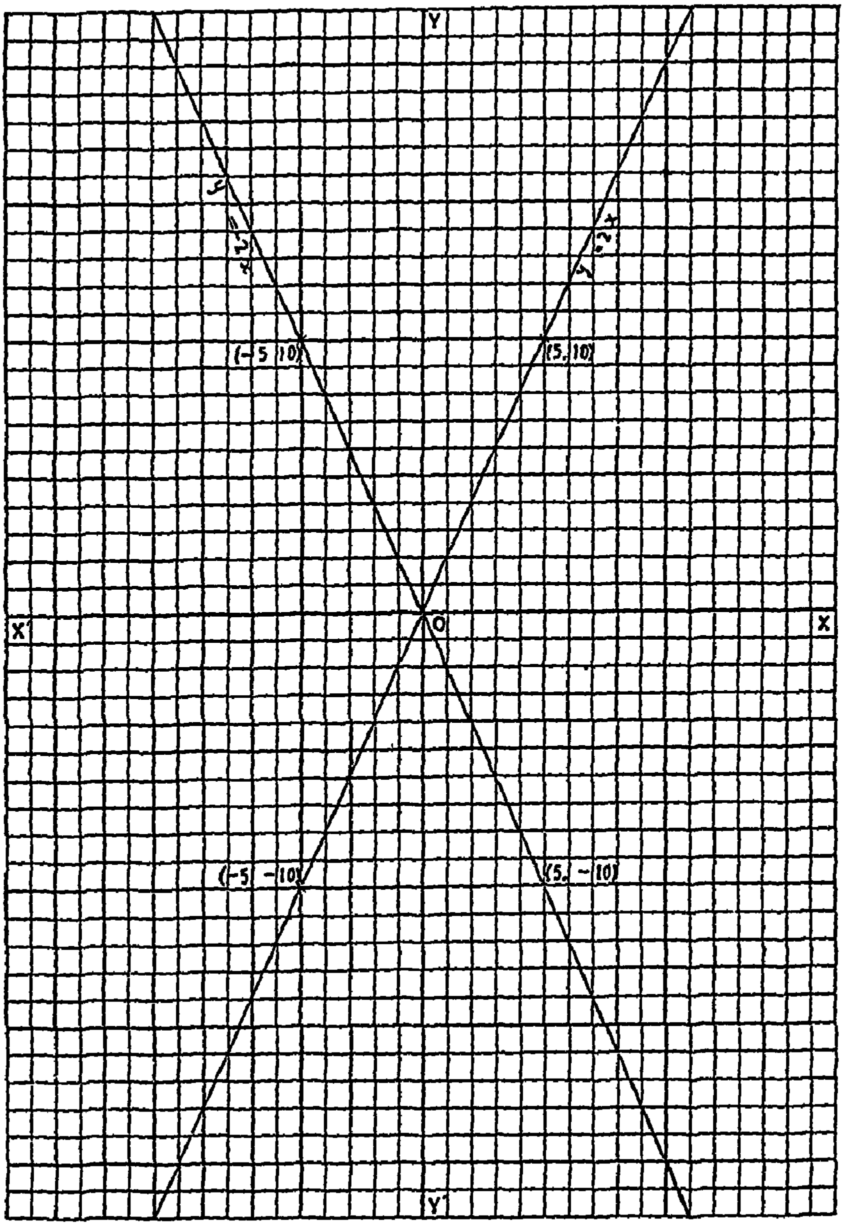
From the given equation, we have

$$\left.\begin{aligned} y^2-4x^2&=0 \\ \text{or,}\quad (y+2x)(y-2x)&=0 \end{aligned}\right\}$$

Clearly, the given equation is satisfied by (i) all those points which satisfy the equation $y+2x=0$, and also (ii) by all those points which satisfy the equation $y-2x=0$

Hence, **the required graph consists of two straight lines,** one being the graph of the equation $y+2x=0$, and the other being the graph of the equation $y-2x=0$.

Hence, the required graph is as shown below ·

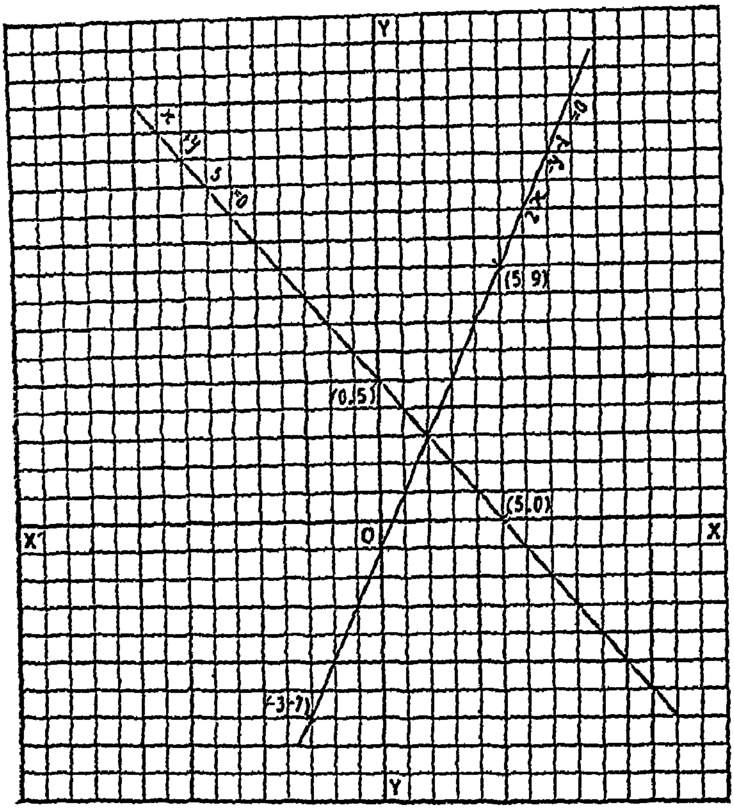


Example 4. Draw the graph of the equation $2x^2+xy-y^2-11x+4y+5=0$

Factorising the left-side of the given equation, we have

$$(x+y-5)(2x-y-1)=0$$

Obviously, the given equation is satisfied (i) by all those points which satisfy the equation $x+y-5=0$ as well as (ii) by all those points which satisfy the equation $2x-y-1=0$



Hence, **the required graph consists of two straight lines,** one being the graph of the equation $x+y-5=0$ and the other being the graph of the equation $2x-y-1=0$, as shown in the diagram

256. Thus, it is clear from the above examples that whenever a quadratic equation can be expressed in the form $XY=0$, where X and Y are expressions of the first degree in x and y, the graph consists of a pair of straight lines, which are respectively the graphs of the equations $X=0$ and $Y=0$

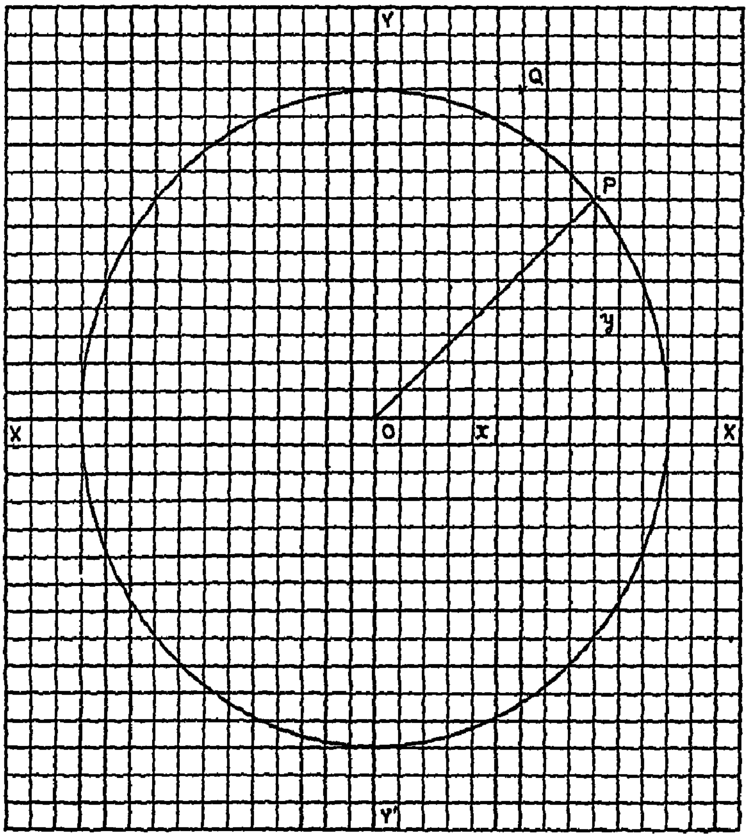
When, however, a quadratic equation cannot be expressed in the form $XY=0$, its graph is a **curve.** We shall now proceed to consider a few graphs of this nature.

257. Draw the graph of the equation $x^2+y^2=36$.

Let twice the length of a side of a small square represent the unit of length

With centre O and a radius equal to 6 units of length describe a circle, as in the diagram Then this circle will be the required graph

Take *any* point P on the circle, and let its co-ordinates be denoted by x and y; evidently then $x^2+y^2=OP^2=36$ But if a point, such as Q, be taken anywhere *not on the circle*, it is easy to see that its co-ordinates will *not* satisfy the given equations



Thus it is shown that the co-ordinates of every point on the circle, and of no other point satisfy the given equation Hence the circle drawn is the required graph

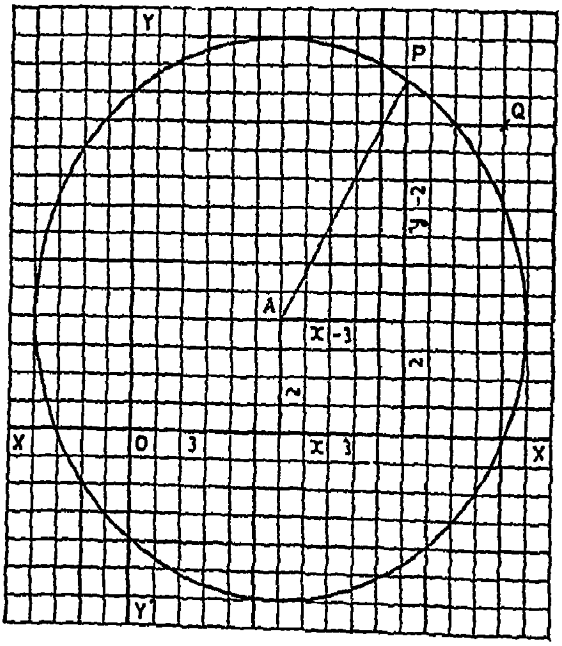
258. Draw the graph of the equation $(x-3)^2+(y-2)^2=25$.

Let twice the length of a side of a small square represent the unit of length.

Let A be the point (3, 2). With centre A and a radius equal to 5 units of length describe a circle as in the diagram. Then this circle will be the required graph.

Take *any* point P on the circle, and let its co-ordinates be denoted by x and y. Now from the diagram it is clear that AP is the hypotenuse of a right-angled triangle of which the sides are $(x-3)$ and $(y-2)$ units of length respectively.

Hence, $(x-3)^2+(y-2)^2=AP^2=25$, which shows that the co-ordinates of P satisfy the given equation. But if a point, such as Q, be taken anywhere *not on the circle*, it is easy to see that its co-ordinates will *not* satisfy the given equation.



Thus it is clear that the co-ordinates of every point on the circle and of no other point, satisfy the given equation. Hence the circle described is the required graph.

Note 1 ***The graph of*** $(x+2)^2+(y+5)^2=49$. *It may be shewn as above that the graph of the equation* $(x+2)^2+(y+5)^2=49$ *is a circle of which the centre is the point* $(-2,-5)$, *and the radius is equal to 7 units of length.*

Note 2 ***The graph of*** $x^2+y^2-8x+10y+25=0$. *The equation* $x^2+y^2-8x+10y+25=0$ *can be easily reduced to the form* $(x-4)^2+(y+5)^2=16$. *Hence its graph is a circle of which the centre is the point* $(4,-5)$ *and the radius is equal to 4 units of length.*

Example 1. Solve graphically $x^2-6x-12=0$.

The equation may be written in the form

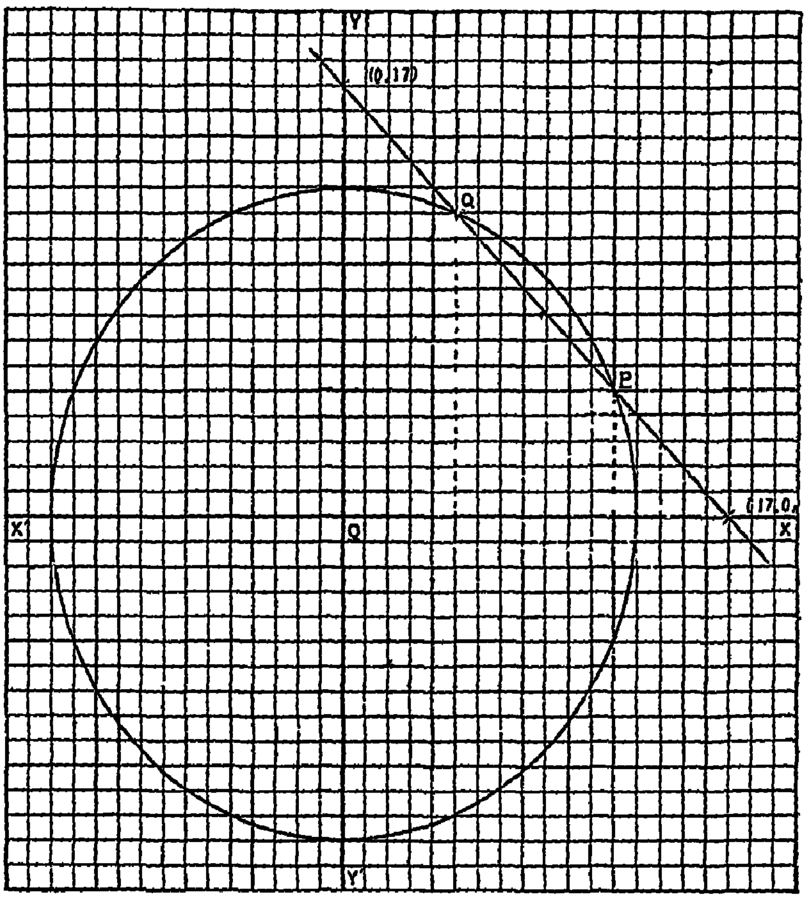
$$(x^2-6x+9)+4=25, \text{ i.e., } (x-3)^2+2^2=25$$

The roots of the given equation are the abscissæ of the points where the line $y=0$ (i.e., the ***x*-axis**) cuts the circle $(x-3)^2+(y-2)^2=25$, [for, putting $y=0$ in the equation of the circle, we have $(x-3)^2+(y-2)^2=25$, i.e., $(x-3)^2+4=25$.]

Hence, drawing the circle $(x-3)^2+(y-2)^2=25$ as in Art. 258, we notice from the diagram that these abscissæ are 7·6 and $-1·6$ approximately.

$\therefore$ The required roots are 7·6 and $-1·6$ approximately.

Example 2. Trace the graph of (i) $x^2+y^2=169$ and (ii) $x+y=17$. Find the co-ordinates of their points of intersection.

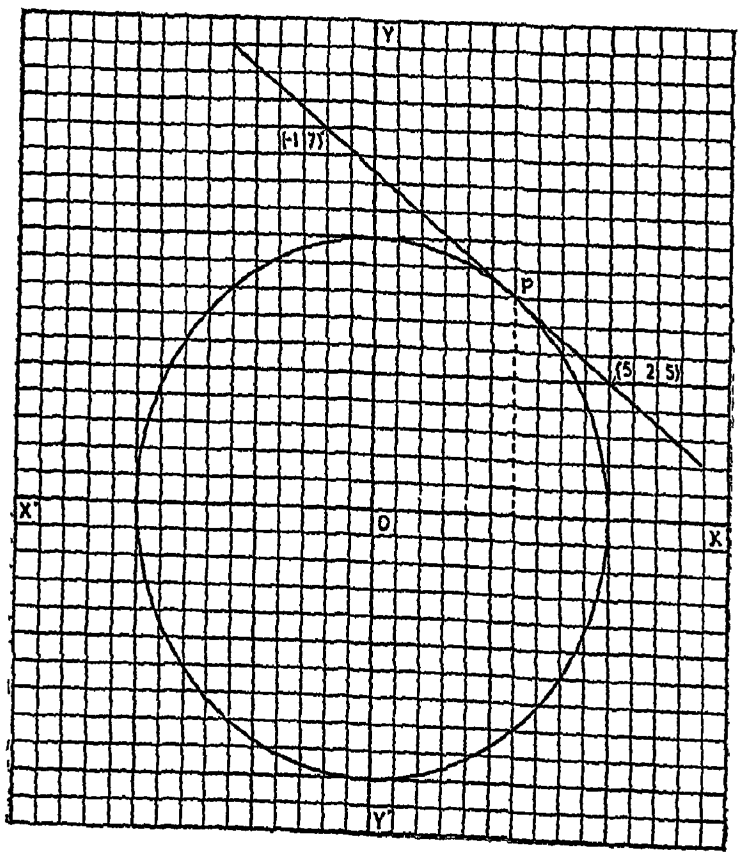


The graph of $x^2+y^2=169=13^2$ is a circle with the centre at the origin and radius equal to 13 units The graph of $x+y=17$ is a straight line passing through the points (17, 0) and (0, 17) Taking the side of a small square as the unit of length and drawing the graphs, they will intersect at P (12, 5) and Q(5, 12) as in the diagram

Note. ***To solve graphically the equation*** $\left.\begin{aligned} x^2+y^2&=169 \\ x+y&=17 \end{aligned}\right\}$

we notice that the co-ordinates of each of the above points P and Q satisfy both the equations and are, therefore, the required solutions Thus, the roots are $\left.\begin{aligned} x&=12 \\ y&=5 \end{aligned}\right\}$ *and* $\left.\begin{aligned} x&=5 \\ y&=12 \end{aligned}\right\}$.

Example 3. Show that the graph of $3x+4y=25$ touches that of $x^2+y^2=25$, and find the co-ordinates of the point of contact [C U 1911]



The graph of $x^2+y^2=25=5^2$ is a circle with its centre at the origin and radius equal to 5 units. The graph of $3x+4y=25$ is a straight line passing through $(5, 2.5)$ and $(-1, 7)$ Taking *twice the side of a small square as the unit of length* and drawing the graphs, we find that they touch at $P(3, 4)$ as in the diagram

EXERCISE 135.

Draw the graphs of the following equations

1. $x^2+y^2=81$ **2.** $(x-5)^2+(y-6)^2=49$.

3. $(x+6)^2+(x-7)^2=100$

4. $x^2+y^2-8x-14y+1=0$

5. $x^2+y^2+14x-16y+32=0$

6. $x^2+y^2+12x+18y+92=0$

7. $x^2+y^2-10x+16y-55=0$

Solve graphically

8. $\left.\begin{aligned} x^2+y^2&=100 \\ x+y&=14 \end{aligned}\right\}$. **9.** $\left.\begin{aligned} x^2+y^2&=25 \\ x-y&=1 \end{aligned}\right\}$.

10. $\left.\begin{aligned} x^2+y^2-4x-6y-12&=0 \\ x+y&=12 \end{aligned}\right\}$.

11. $x^2-4x-12=0$ [The roots are the abscissæ of the points where the x-axis cuts $x^2+y^2-4x-6y-12=0$, etc]

12. $x^2-6x-16=0$

13. Draw the graphs of $x^2+y^2=36$ and $3x-4y=30$. Show that they touch at $(3.6, -4.8)$

14. Draw the graph of $x^2+y^2-4x-6y-23=0$ and find its tangents parallel to the co-ordinate axes

15. Draw the graph of $x^2+y^2-10x-10y+25=0$ and show that it touches the co-ordinate axes Find the co-ordinates of the points of contact.

16. Draw the graphs of the following equations:

(1) $x^2=16$. (2) $x^2-5x+6=0$.

(3) $5x^2-3x-2=0$. (4) $y^2-3y=0$;

(5) $xy=0$. (6) $x^2-3xy+2y^2=0$:

(7) $x^2-y^2+4y-4=0$. (8) $(x+3)^2=4(y-5)^2$

17. Draw the graph of $5x^2-24xy-5y^2=0$ and show that they are two perpendicular straight lines

18. Find the angle between the straight lines which represent the graphs of

(i) $xy=0$ (ii) $(x-3)(y-2)=0$,

(iii) $(3x-2y+5)(2x-3y+2)=0$

(iv) $(7x-6y+3)(6x-7y-8)=0$

258. Draw the graph of the equation $4x^2+9y^2=36$.

(1) When $x=0$ we have $y^2=4$ and therefore $y=\pm 2$. Hence the points $(0, 2)$ and $(0, -2)$ are on the required graph

(2) When $y=0$ we have $x^2=9$ and therefore $x=\pm 3$. Hence the points $(3, 0)$ and $(-3, 0)$ are on the required graph

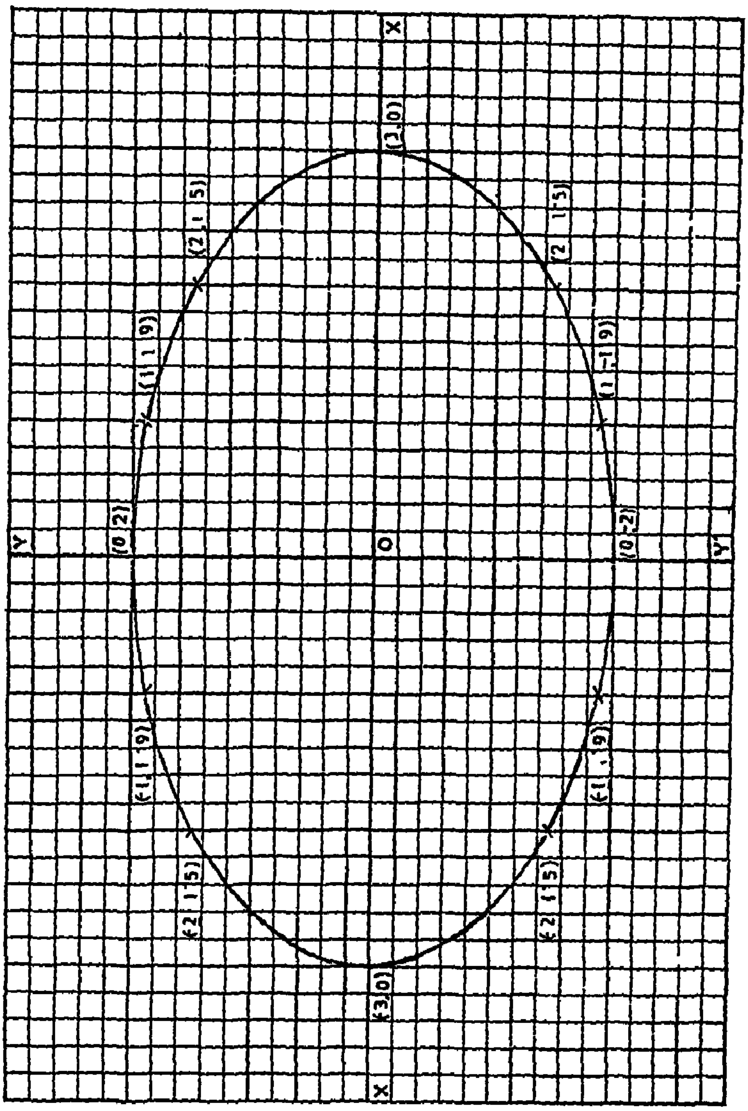
(3) When $x=\pm 1$ we have $9y^2=32$ and therefore $y=\pm \frac{4}{3}\sqrt{2}=\pm\frac{4\times 1.414}{3}=\pm\frac{5.656}{3}=\pm 1.885=\pm 1.9$ approximately. Hence the four points $(1, 1.9)$, $(1, -1.9)$, $(-1, 1.9)$ and $(-1, -1.9)$ are on the required graph

(4) When $x=\pm 2$ we have $9y^2=20$, and therefore $y=\pm\frac{2}{3}\sqrt{5}=\pm\frac{2\times 2.236}{3}=\pm\frac{4.472}{3}=\pm 1.490=\pm 1.5$ nearly.

Hence the four points $(2, 1.5)$, $(2, -1.5)$, $(-2, 1.5)$ and $(-2, -1.5)$ are on the required graph.

Corresponding values of x and y may be tabulated as follows

x	0	0	3	−3	1	1	−1	−1	2	2	−2	−2
y	2	−2	0	0	1 9	−1 9	1 9	−1 9	1 5	−1 5	1 5	−1 5



Let us now plot the twelve points as found above (taking 5 times the side of a small square as the unit of length) and draw a free-hand curve through them, as in the diagram on the last page

The curve so drawn is the required graph.

Note 1. *Evidently the curve is* ***symmetrical*** *about the axis of* x, *i e, every chord at right angles to the axis of* x *is bisected by it. Similarly the curve is also symmetrical about the axis of* y.

Note 2 *The curve lies entirely within the space enclosed by the four straight lines* $x=3$, $x=-3$, $y=2$, $y=-2$, *since from the given equation it is obvious that* x *is imaginary when* $y > 2$ *and* < -2 *and* y *is imaginary when* $x > 3$ *and* < -3

A curve of this class is called an ***Ellipse.***

Example 1. Draw the graph of the expression

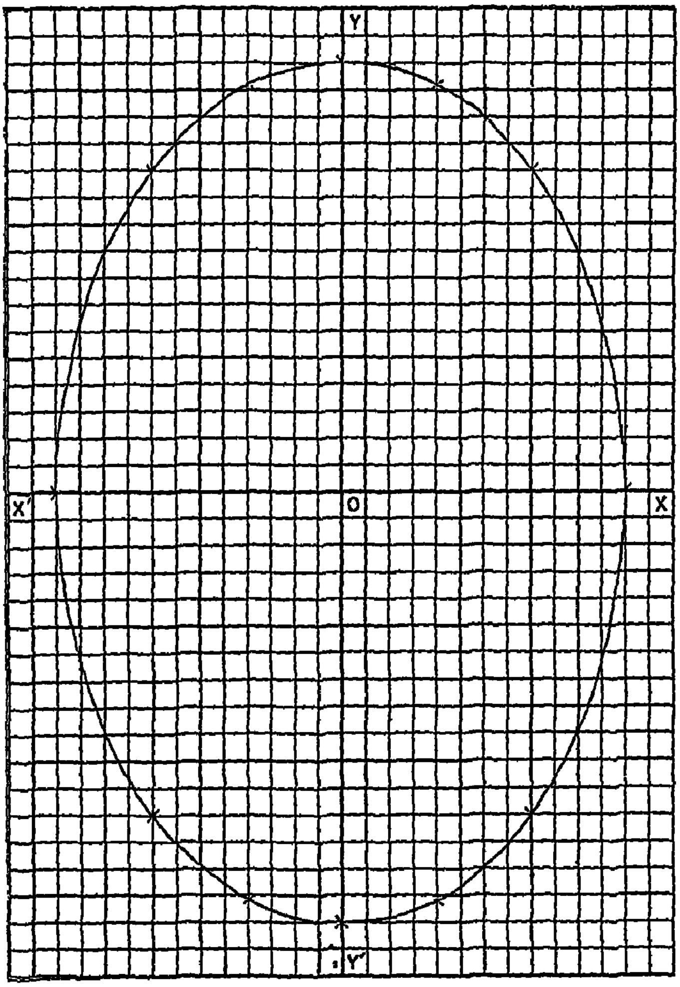
$$\frac{4}{3}\sqrt{9-x^2}.$$

Let $y=\frac{4}{3}\sqrt{9-x^2}$

For each value of x, there will be two equal and opposite values of y Thus (1) when $x=0$, $y=\pm 4$; (2) when $y=0$, $x=\pm 3$; (3) when $x=\pm 1$, $y=\pm\frac{4}{3}\sqrt{8}=\pm 3.8$ approximately; (4) when $x=\pm 2$, $y=\pm\frac{4}{3}\sqrt{5}=\pm 3.0$ approximately

The corresponding values of x and y may be arranged in a tabular form as follows·

x	0	0	3	−3	1	1	−1	−1	2	2	−2	−2
y	4	−4	0	0	3.8	−3.8	3.8	−3.8	3	−3	3	−3



Plotting these twelve points (taking 4 times the side of a small square as the unit of length) and drawing a free-hand curve through them as shown in the diagram we obtain the required graph.

Example 2. Draw the graph of $4(x-2)^2+9(y-3)^2=36$

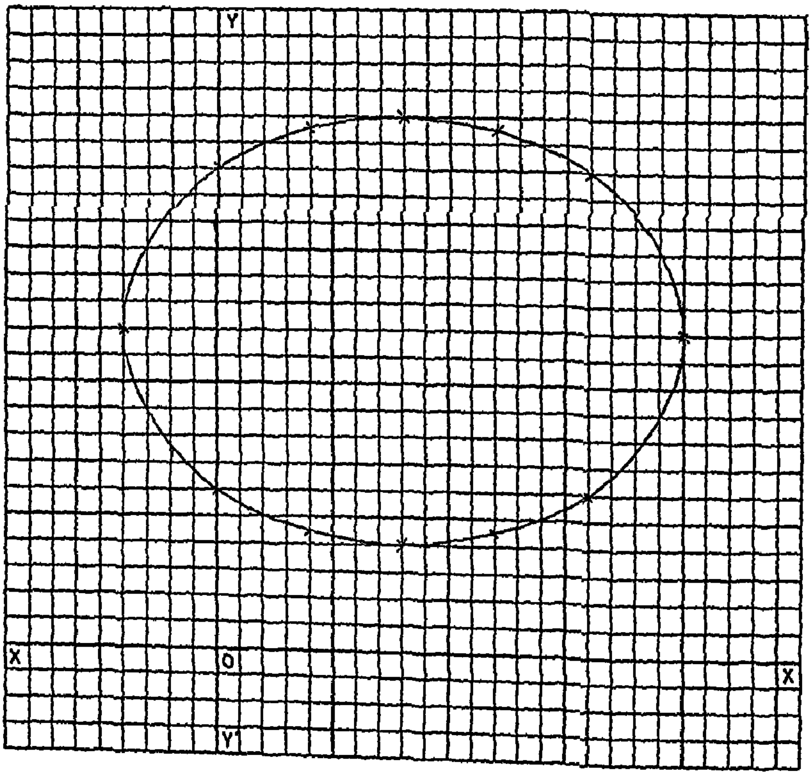
Re-writing the equation, we have

$$9(y-3)^2=36-4(x-2)^2,$$

or, $$y-3=\pm\tfrac{2}{3}\sqrt{9-(x-2)^2}$$

Hence, for each value of $x-2$, we get two values of $y-3$ from which the corresponding values of x and y may be tabulated as follows:

x	2	2	5	−1	1	1	3	3	4	4	0	0
y	5	1	3	3	4·9	1·1	4 9	1 1	4 5	1 5	4 5	1 5



Plotting these twelve points (taking 4 times the side of a small square as the unit of length) and drawing a free-hand curve through them as shown in the diagram we get the required graph

Example 3. Draw the graph of $4x^2+9y^2-16x-54y+61=0$

The left-hand side of the given equation

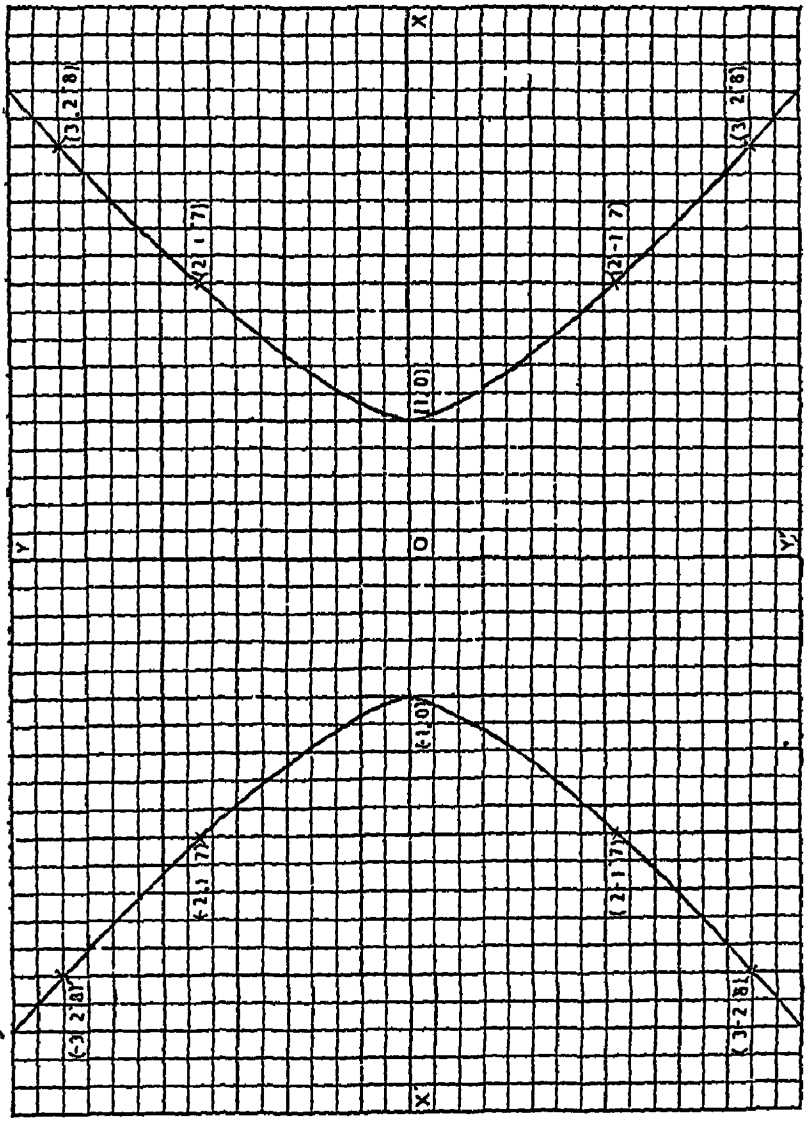
$$=4(x^2-4x)+9(y^2-6y)+61$$
$$=4\{(x-2)^2-4\}+9\{(y-3)^2-9\}+61$$
$$=4(x-2)^2+9(y-3)^2-36$$

∴ The equation is $4(x-2)^2+9(y-3)^2-36=0$,

or, $$4(x-2)^2+9(y-3)^2=36.$$

To draw its graph see example 2 above

260. Draw the graph of the equation $x^2-y^2=1$.



(1) When $x=0$, we have $y^2=-1$, and therefore y is *imaginary* This shows that the graph does not cut the axis of y

(2) When $y=0$, we have $x^2=1$, and therefore $x=\pm 1$. Hence the points (1, 0) and (−1, 0) are on the required graph

(3) When $x = \pm 2$, we have $y^2 = 3$, and therefore $y = \pm\sqrt{3} = \pm 1.732 \ldots = \pm 1.7$ approximately. Hence the four points $(2, 1.7)$, $(2, -1.7)$, $(-2, 1.7)$ and $(-2, -1.7)$ are on the required graph.

(4) When $x = \pm 3$, we have $y^2 = 8$, and therefore $y = \pm 2\sqrt{2} = \pm 2 \times 1.414 \ldots = \pm 2.828 \ldots = \pm 2.8$ approximately. Hence the four points $(3, 2.8)$, $(3, -2.8)$, $(-3, 2.8)$ and $(-3, -2.8)$ are on the required graph.

The corresponding values of x and y may be tabulated as follows

x	1	−1	2	2	−2	−2	3	3	−3	−3
y	0	0	1.7	−1.7	1.7	−1.7	2.8	−2.8	2.8	−2.8

Let us now plot the ten points as found above (taking 5 times the side of a small square as the unit of length) and draw a free-hand curve through them, as in the diagram on the last page.

The curve so drawn is the required graph.

Note 1 *The curve so drawn is evidently symmetrical about the axis of x and also about the axis of y.*

Note 2 *The curve consists of two branches, one lying entirely on the right of the line x=1 and the other lying entirely on the left on the line x=−1.*

A curve of this class is called a ***Hyperbola.***

Example 1. Trace the graph of (i) $x^2 - y^2 = 1$, and (ii) $x^2 + y^2 = 1$. Show that they touch each other.

Draw the graph of $x^2 - y^2 = 1$ as above and the graph of the circle $x^2 + y^2 = 1$ on the *same scale*. It will be found that they touch each other at the points $(1, 0)$ and $(-1, 0)$.

Example 2. Trace the graphs of (i) $x^2 - y^2 = 1$ and (ii) $x = 2y$. Find the co-ordinates of their points of intersection.

Draw the Hyperbola $x^2 - y^2 = 1$ and the straight line $x = 2y$ on the *same scale.* Produce the straight line, if necessary, to meet the Hyperbola. They will be found to intersect at *two* points whose co-ordinates are $(1.2, .6)$ and $(-1.2, -.6)$ approximately.

261. Draw the graph of the equation $y=x^2$.

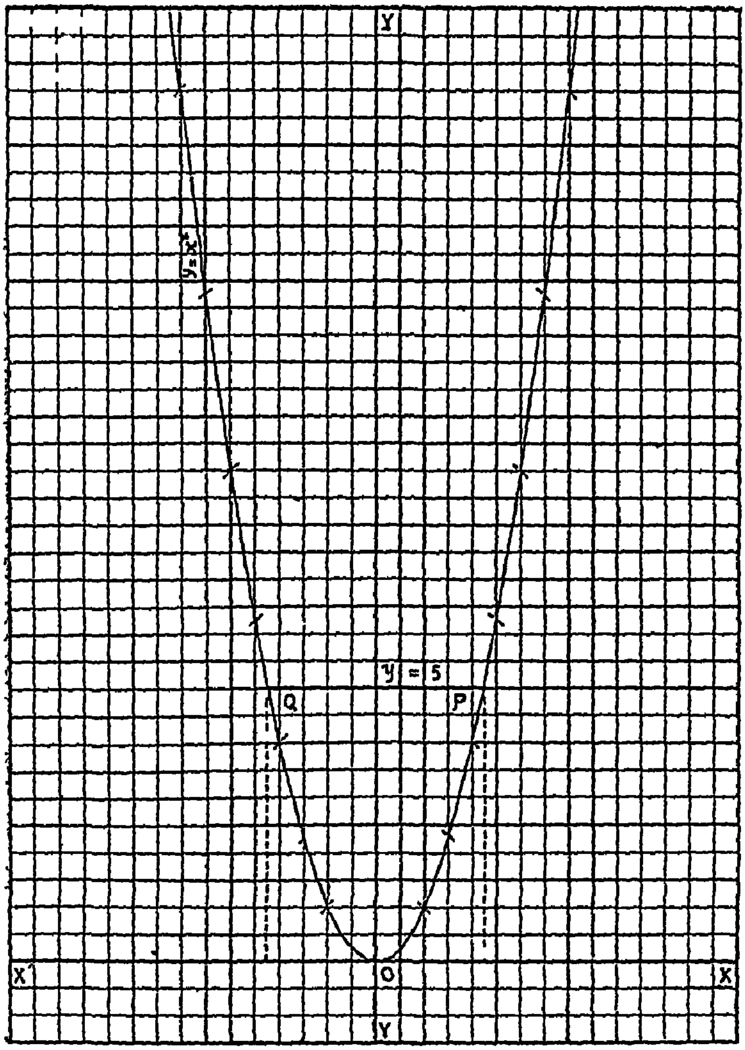
Evidently the following points are on the required graph and their co-ordinates may be tabulated as follows

x	0	1	−1	1.5	−1.5	2	−2	2.5	−2.5	3	−3	3.5	−3.5	4	−4
y	0	1	1	2.25	2.25	4	4	6.25	6.25	9	9	12.25	12.25	16	16

Let 2 times the side of a small square be the unit of length.

Let us now plot the points found above and draw a curve through them free-hand, as in the following diagram:

The curve so drawn is the required graph.



Note 1 *Since $y=x^2$, we have $x=\pm\sqrt{y}$, x is imaginary when y is negative Hence, no point of the curve can have a negative ordinate and, therefore, no part of the curve can lie below the x-axis The curve passes through the origin, lies entirely above the x-axis and extends upwards to infinity*

Note 2 *Every chord drawn perpendicular to OY is bisected by it as can be easily verified Hence the curve drawn above is symmetrical about the axis of y This is also evident from the fact that if the paper be folded about OY the left-hand portion of the curve entirely coincides with the right-hand portion.*

A curve of this class is called a **Parabola.**

Note 3 ***The graph of $y=-x^2$*** *The curve $y=x^2$ lies entirely above the axis of x, and extends upwards to infinity It is easy to see that the graph of the equation $y=-x^2$ would be an equal curve being entirely* **below** *the axis of x and extending downwards to infinity*

Note 4 ***To determine the square root of a number from the graph of $y=x^2$*** *The abscissa of any point on the curve is evidently the square root of the ordinate Hence, when the graph of the equation $y=x^2$ is drawn by measuring the abscissa of any point on the graph we can determine the* **square root** *of the number which represents the ordinate Thus, in the diagram, the ordinates of P or Q represent 5 . The square root of 5 = the abscissa of P or Q = 2 25, or − 2 25 approximately [2 sides of a small square = 1 unit]*

262. Draw the graph of the expression $3-4x-2x^2$.

The required graph is the same as that of the equation $y=3-4x-2x^2$.

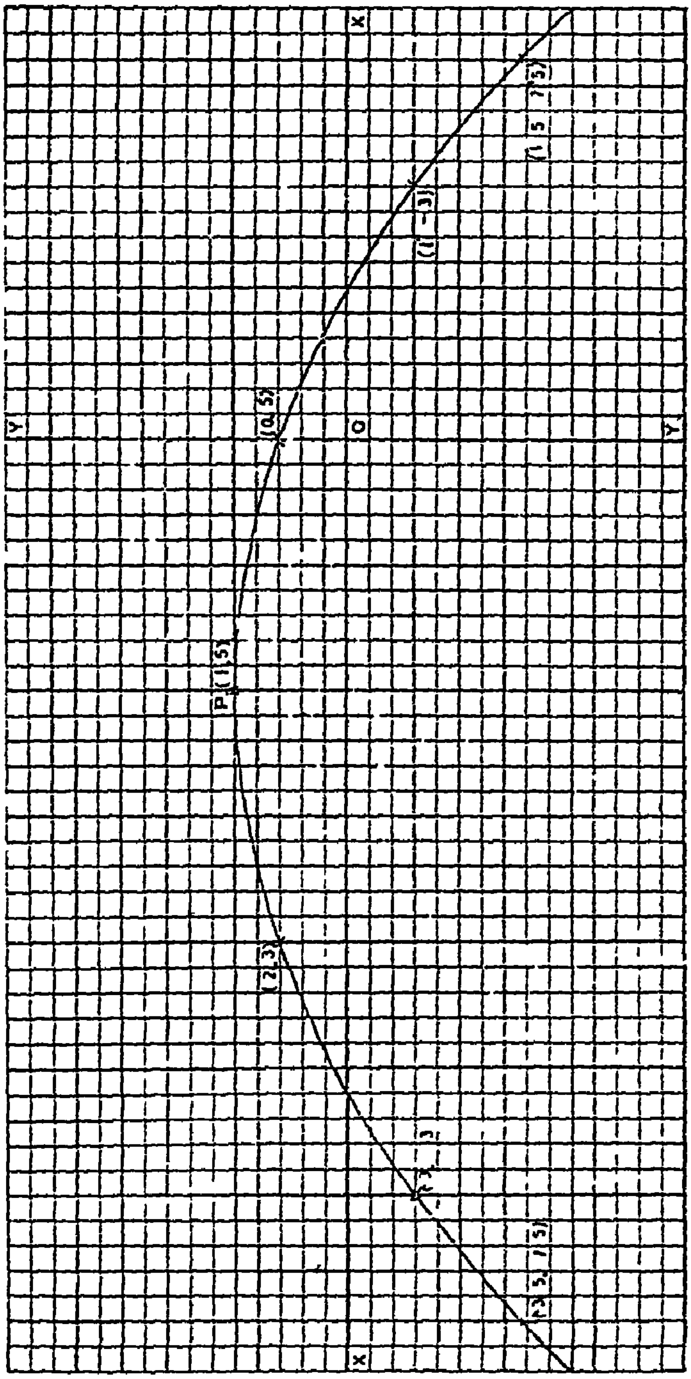
It is easy to see that the following points are on the required graph

$$\left.\begin{matrix}x=0\\y=3\end{matrix}\right\},\quad \left.\begin{matrix}x=1\\y=-3\end{matrix}\right\},\quad \left.\begin{matrix}x=1\ 5\\y=-7\ 5\end{matrix}\right\},$$

$$\left.\begin{matrix}x=-1\\y=5\end{matrix}\right\},\quad \left.\begin{matrix}x=-2\\y=3\end{matrix}\right\},\quad \left.\begin{matrix}x=-3\\y=-3\end{matrix}\right\},\quad \left.\begin{matrix}x=-3\ 5\\y=-7\ 5\end{matrix}\right\}.$$

Take ten sides of a small square as the unit for measuring x, and one side of a small square as the unit for measuring y.

Let us now plot the above points and draw a curve through them free-hand, as in the diagram on the next page.



The curve so drawn is the required graph

Note *The graph of any expression of the form* ax^2+bx+c *is a parabola*

263. Graphical solution of Quadratic Equations.

Example 1. To solve graphically the equation

$$3-4x-2x^2=0$$

Draw the graph of $y=3-4x-2x^2$ as in the last article.

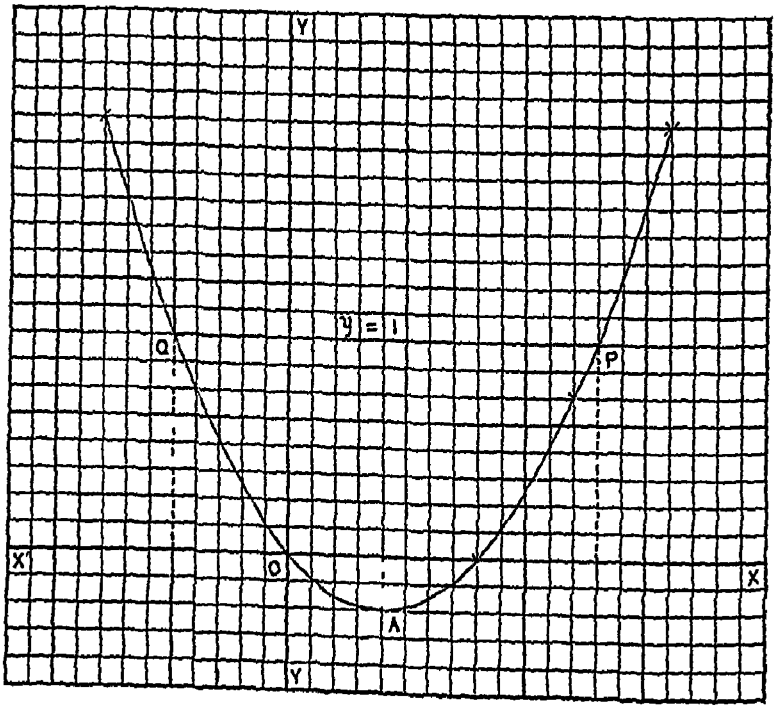
From the figure it is evident that $y=0$, when x is approximately equal to 6 or -2 6 Hence, $3-4x-2x^2=0$, when $x=$ 6 or -2 6 approximately, in other words, the roots of the equation $3-4x-2x^2=0$ are 6 and -2 6 approximately From this it is clear that *the roots of the equation* $3-4x-2x^2=0$ *are the abscissæ of the points where the graph of the expression* $3-4x-2x^2$ *cuts the axis of* x

Example 2. Trace the graph of $y=x^2-x$ from $x=-1$ to $x=2$ and therefrom obtain an approximate solution of the equation $1=x^2-x$ [C U Entr Paper, 1917]

The following points evidently lie on the graph·

x	-1	$-\frac{1}{2}$	0	$\frac{1}{2}$	1	$1\frac{1}{2}$	2
y	2	$\frac{3}{4}$	0	$-\frac{1}{4}$	0	$\frac{3}{4}$	2

Taking 8 sides of a small square as the unit of length, the graph will be as shown in the diagram



If we now put $y=1$ the equation $y=x^2-x$ becomes $1=x^2-x$ Hence the roots of the equation $1=x^2-x$ are the abscissæ of the points P and Q of the graph of $y=x^2-x$, at which the ordinate is 1 P and Q are evidently the points where the line $y=1$ meets the graph From the figure we find that the abscissæ of P and Q are 1 6 and $-$ 6 respectively, which are, therefore, the required solutions

Example 3. Trace the graphs of (i) $y=3x^2$ and (ii) $y=2x+1$ and determine the points where they meet [C U 1915]

Deduce the roots of the equations

$$3x^2=2x+1.$$

Evidently the corresponding values of x and y on $y=3x^2$ may be tabulated as follows .

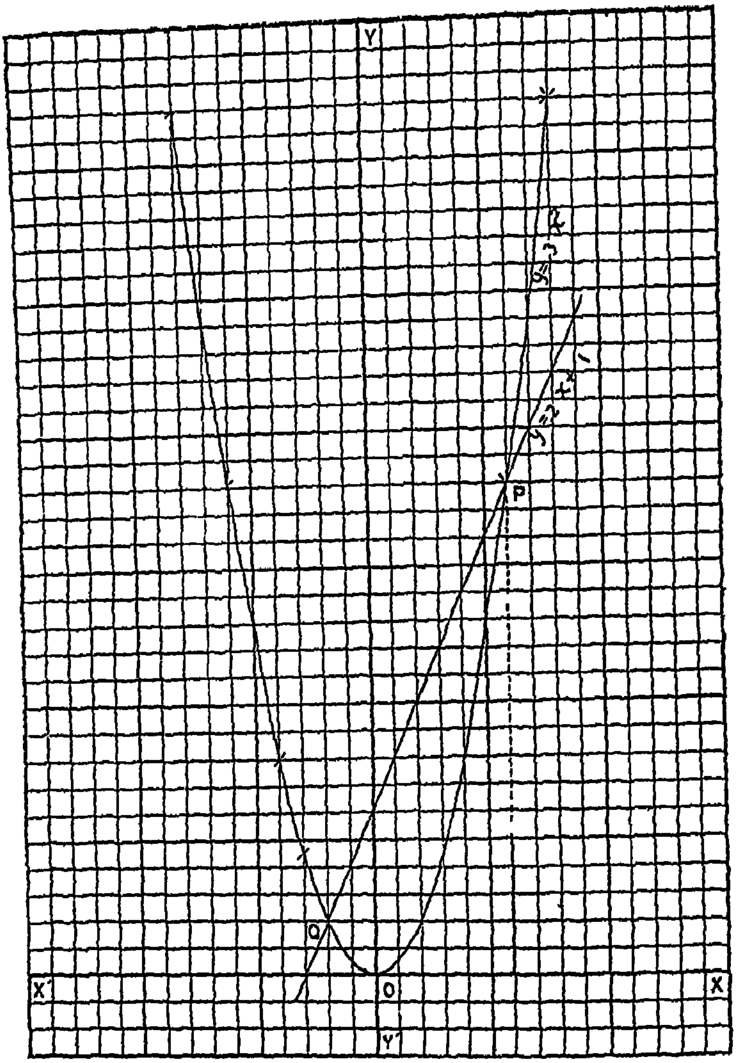
x	0	$\frac{1}{3}$	$-\frac{1}{3}$	$\frac{2}{3}$	$-\frac{2}{3}$	1	-1	$1\frac{1}{3}$	$-1\frac{1}{3}$
y	0	$-\frac{1}{3}$	$\frac{1}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	3	3	$\frac{16}{3}$	$\frac{16}{3}$

Also, the points $\left.\begin{matrix} x=0 \\ y=1 \end{matrix}\right\}$ and $\left.\begin{matrix} x=\frac{1}{2} \\ y=2 \end{matrix}\right\}$ lie on the straight line $y=2x+1$

Taking six times the side of a small square as the unit of length, the graphs will be as shown in the diagram on the next page

Let the straight line meet the parabola at P and Q whose co-ordinates are found from the diagram to be (1, 3) and $(-\frac{1}{3}, \frac{1}{3})$ respectively

The abscissæ of the points common to the graphs of $y=3x^2$ and $y=2x+1$ are evidently the roots of $3x^2=2x+1$ But, from the figure, these abscissæ are 1 and $-\frac{1}{3}$, which are, therefore, the required roots of $3x^2=2x+1$

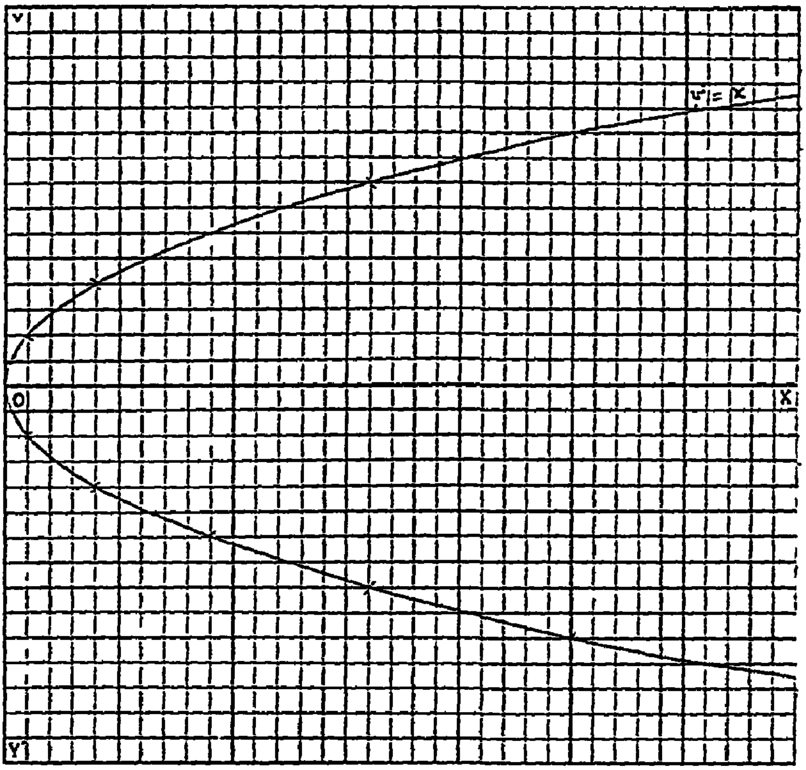


264. Draw the graph of $y^2 = x$.

We have $y = \pm\sqrt{x}$ The corresponding values of x and y may be tabulated as follows.

x	0	25	25	1	1	2 25	2 25	4	4	6 25	6 25
y	0	·5	− 5	1	−1	1 5	−1 5	2	−2	2 5	−2 5

Let four sides of a small square be the unit of length. Now, plotting the points found above and drawing a curve through them free-hand, the graph will be as in the diagram.



Note 1 *Since for every point of the graph, $y = \pm\sqrt{x}$ and is, therefore, imaginary when x is negative, it follows that no point of the graph can have a negative abscissa, i e, no part of the graph lies on the negative side of the y-axis This graph, therefore, lies on the positive side of the y-axis and extends to infinity on that side It is easy to see that the curve is symmetrical about the x-axis*

Note 2 *The graph of $y^2 = -x$ is evidently an equal curve turned in the opposite direction on the negative side of the x-axis*

265. Maximum and Minimum values of Quadratic expressions.

Example 1. Show graphically that the expression $3 - 4x - 2x^2$ is positive for all values of x between $-2\,6$ and 6 and find its maximum value

Let $y = 3 - 4x - 2x^2$

Drawing the graph of $y = 3 - 4x - 2x^2$ as in Art 262, we find that for all values of x between $-2\,6$ and 6 the curve lies

above the x-axis and $\therefore$ the ordinates are positive, and for values of x greater than ·6 and less than $-2·6$, the curve is below the axis of x and $\therefore$ the ordinates are negative. But the ordinate $(y) = 3 - 4x - 2x^2$.

Hence, $3 - 4x - 2x^2$ is positive for all values of x between $-2·6$ and ·6.

Also, we notice, from the figure that the ordinate is greatest at the point $P(-1, 5)$, its greatest value being 5.

$\therefore$ The maximum value required $= 5$.

Example 2. Show graphically that the expression $x^2 - x$ is negative for all values of x between $x=0$ and $x=1$. Find its minimum value.

Let $y = x^2 - x$.

Drawing the graph of $y = x^2 - x$ as in Art. 263, example 2 (see the diagram on page 568), we find that for all values of x between $x=0$ and $x=1$ the curve is below the x-axis and $\therefore$ the ordinates are negative.

But the ordinate $(y) = x^2 - x$.

Hence, $x^2 - x$ is negative for all values of x between $x=0$ and $x=1$.

Also, it is evident from the figure that y (i.e., $x^2 - x$) has the minimum value $-\frac{1}{4}$ at the point A.

266. Draw the graph of the equation $xy = 1$.

It is easy to see that the following points are on the required graph:

$$\left.\begin{matrix} x = ·1 \\ y = 10 \end{matrix}\right\}, \quad \left.\begin{matrix} x = ·2 \\ y = 5 \end{matrix}\right\}, \quad \left.\begin{matrix} x = ·4 \\ y = 2·5 \end{matrix}\right\},$$

$$\left.\begin{matrix} x = ·5 \\ y = 2 \end{matrix}\right\}, \quad \left.\begin{matrix} x = ·8 \\ y = 1·25 \end{matrix}\right\}, \quad \left.\begin{matrix} x = 1 \\ y = 1 \end{matrix}\right\}, \quad \left.\begin{matrix} x = 2 \\ y = ·5 \end{matrix}\right\}$$

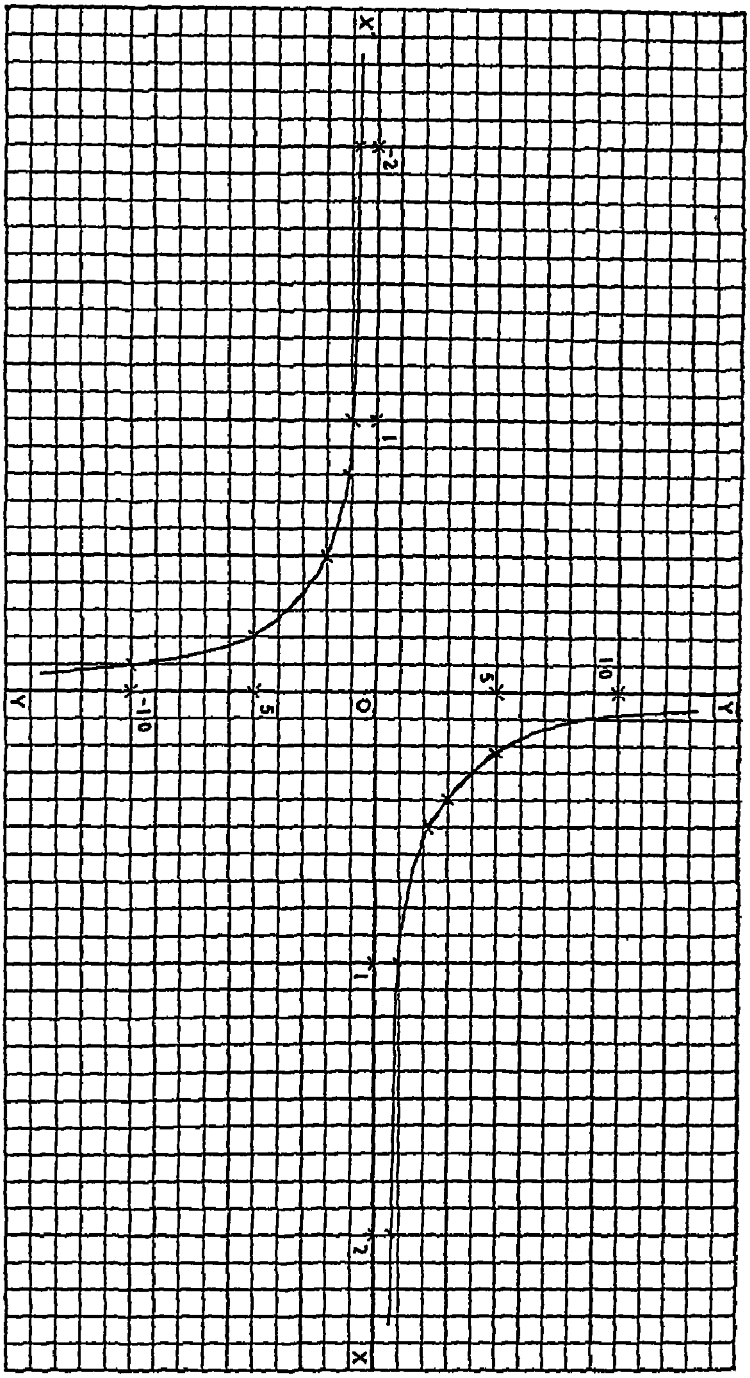
Evidently also the following points are on the required graph:

$$\left.\begin{matrix} x = -·1 \\ y = -10 \end{matrix}\right\}, \quad \left.\begin{matrix} x = -·2 \\ y = -5 \end{matrix}\right\}, \quad \left.\begin{matrix} x = -·4 \\ y = -2·5 \end{matrix}\right\}, \quad \left.\begin{matrix} x = -·5 \\ y = -2 \end{matrix}\right\},$$

$$\left.\begin{matrix} x = -·8 \\ y = -1·25 \end{matrix}\right\}, \quad \left.\begin{matrix} x = -1 \\ y = -1 \end{matrix}\right\}, \quad \left.\begin{matrix} x = -2 \\ y = -·5 \end{matrix}\right\}.$$

Let one inch be the unit for measuring x and one-tenth of an inch the unit for measuring y.

Let us now plot the points and draw a curve through them free-hand, as in the following diagram.



The curve so drawn is the required graph

Note 1 *As x diminishes from 1 to zero, y increases from 1 to infinity, and as x diminishes from zero to -1, y increases from negative infinity to -1*

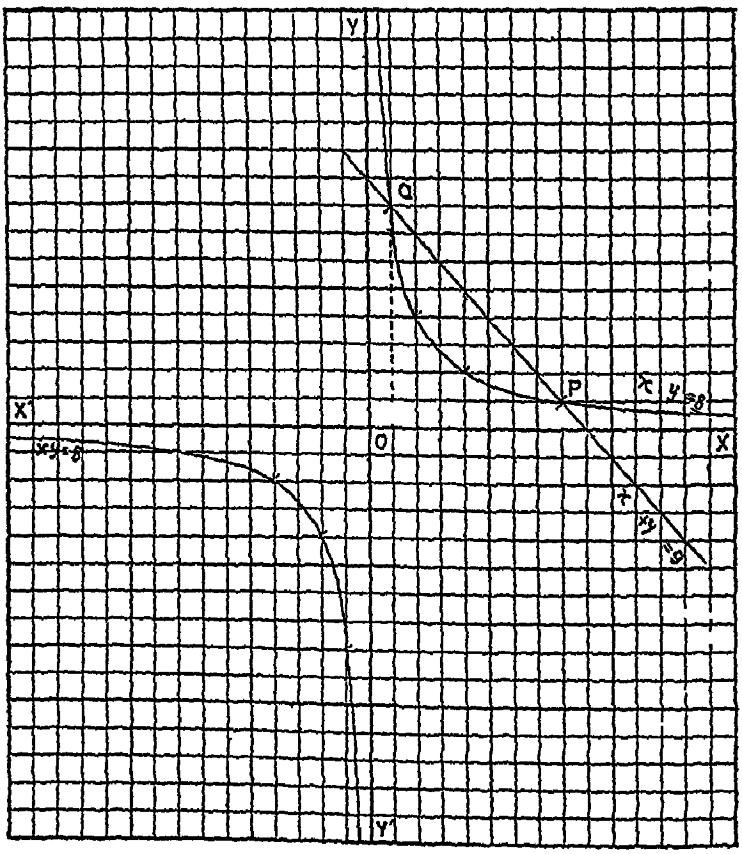
Note 2 *As x increases from 1 to infinity, y diminishes from 1 to zero, and as x diminishes from -1 to negative infinity, y increases from -1 to zero.*

Note 3 *The graph consists of two branches, one lying between OX and OY, and the other between OX′ and OY′*

Note 4 *The more we move towards the right or left of O, the nearer does the curve approach the axis of x, whilst the more we move upwards and downwards from O, the nearer does the curve approach the axis of y But in no case does the curve* **meet** *the axis except at an infinite distance from O Hence, each of the axis is said to be an* ***Asymptote*** *to the curve*

Note 5 *A curve of this kind is called a* ***Rectangular Hyperbola.***

Example. Draw the graphs of (i) $xy=8$ and (ii) $x+y=9$. Find the co-ordinates of their points of intersection.



Drawing the graph of $xy=8$ by the above method and the graph of the straight line $x+y=9$ in the same figure on the same scale, as in the diagram it will be found that they intersect at two points P and Q whose co-ordinates are

$$\left.\begin{matrix}x=8\\y=1\end{matrix}\right\} \quad \text{and } \left.\begin{matrix}x=1\\y=8\end{matrix}\right\} \text{ respectively}$$

EXERCISE 136.

Draw the graphs of the following equations.

1. $x^2+4y^2=4$. **2.** $4x^2+9y^2=1$.

3. $25x^2+y^2=25$ **4.** $16x^2+9y^2=1$ **5.** $x^2-4y^2=4$.

6. $y^2-x^2=1$ **7.** $4x^2-y^2=16$ **8.** $y^2-9x^2=9$.

9. In one and the same diagram draw the graphs of $4x^2-9y^2=0$ and $4x^2-9y^2=36$

10. In one and the same diagram draw the graphs of $9y^2-4x^2=0$ and $9y^2-4x^2=36$

11. Draw the graphs of the equation $5y^2=x^2-10$ taking the unit for measuring y five times as large as that for measuring x

12. Draw the graph of the equation $x^2-4x+2y=0$ taking the unit for measuring y twice as large as that for measuring x

13. Draw the graph of the equation $y^2+x=0$ taking the unit for measuring x equal to half that for measuring y

14. Draw the graph of the equation $3y=x^2$ taking the same unit for measuring both x and y

15. Find graphically, correct to the first figure after the decimal point the square roots of :

(i) 3; (ii) 5: (iii) 7.

16. Find graphically the minimum value of the expression

(i) $x^2+6x+10$; (ii) $4x^2+4x+5$, (iii) $\frac{1}{2}x^2+4x+1$; and (iv) $2x^2-6x+7$.

17. Find graphically the maximum values of the expression :

(i) $4x-x^2$; (ii) $3+6x-9x^2$. (iii) $12-3x-\dfrac{x^2}{4}$; and (iv) $1+2x-2x^2$.

18. Draw the graphs of the equations (i) $xy=4$ and (ii) $x+y=5$ and find where they intersect

19. Show graphically that (i) the expression $4x-x^2$ is positive for all values of x between 0 and 4; (ii) the expression $x^2+6x+12$ is positive for all values of x and (iii) x^2-4x-5 is negative for all values of x between -1 and 5.

20. Draw the graphs of (i) $xy=-8$ and (ii) $x+y=2$ and find where they intersect

Solve graphically

21. $x^2=4x-3$ **22.** $3x^2=x+2$ **23.** $2x^2-7x+5=0$.

24. $7x^2-2x=5$

25. (i) $\left.\begin{matrix}x^2-y^2=1\\ x=2y\end{matrix}\right\}$, (ii) $\left.\begin{matrix}xy=5\\ x+y=-6\end{matrix}\right\}$;

(iii) $\left.\begin{matrix}y^2=4x\\ y=2x\end{matrix}\right\}$, and (iv) $\left.\begin{matrix}x^2=y\\ x=-2y\end{matrix}\right\}$

CHAPTER XXXVII

ARITHMETICAL PROGRESSION

267. Definition. Quantities are said to be in arithmetical progression when they increase regularly by a common quantity (called the **common difference**)

Thus each of the following series of quantities is in Arithmetical Progression

2	5,	8,	11,	14,	&c
9,	5,	1,	-3,	-7,	&c
a,	$a+b$,		$a+2b$,	$a+3b$,	&c
a,	$a-b$,		$a-2b$,	$a-3b$,	&c

In the first of the above examples the quantities increase by 3, whereas in the second the quantities decrease by 4; so the common differences in these two cases are said to be 3 and -4 respectively Similarly in the third example the common difference is b and in the fourth it is $-b$

N B 'Arithmetical Progression' is briefly written as ***A P.***

268. The **common difference** of the terms of an A.P. is found by subtracting any term of the series from the term following it

Thus, in the series a, $a+b$, $a+2b$, $a+3b$, the common difference $=(a+b)-a=(a+2b)-(a+b) = (a+3b)-(a+2b)=$ $=b$

269. To find the *n*th term of an A.P.

If a be the first term and b the common difference of a series of numbers in Arithmetical Progression, we have the second term $=a+b$, the 3rd term $=a+2b$, the 4th term $=a+3b$, the 10th term $=a+9b$, the 21st term $=a+20b$; and so on Hence, the nth term $=a+(n-1)b$

Example 1. Find the 19th term of the series 10, 8, 6, 4, &c

The first term $=10$, and the common difference $= -2$

Hence the 19th term $=10+18(-2)=10-36= -26$

Example 2. What term of the series 5, 7, 9, 11, &c is 25?

Let the nth term of the given series be the required term; then we must have $25=5+(n-1)2$

$=3+2n$, whence $n=11$.

Thus the 11th term of the given series $=25$

270. Given any two terms of an A.P., to find it completely.

Example 1. The 7th and the 13th term of an A P are 34 and 64 respectively Find the series

Let $a=$ the first term,

$b=$ the common difference of the A P

The 7th term $=a+(7-1)b=a+6b=34$. (1)

and the 13th term $=a+(13-1)b=a+12b=64$. (2)

From (1) and (2) by subtraction,

$6b=30$, i e, $b=5$

Now from (1), $a+6\times5=34$, or, $a=34-30=4$

Hence, the first term and the common difference of the required series are 4 and 5 respectively

$\therefore$ The series is 4, 9, 14, 19, 24,

Example 2. The pth and the qth terms of an A P are c and d respectively Find the series completely

Let $a=$ the first term,

and $b=$ the common difference of the A P.

$\therefore$ The pth term $= a+(p-1)b = c$, ... (1)

and the qth term $= a+(q-1)b = d$. . (2)

Solving equations (1) and (2), a and b can be obtained Thus, by subtraction from (1) and (2), we have,

$$(p-q)b = c-d, \quad \therefore \quad b = \frac{c-d}{p-q}.$$

Also, from (1), $a+(p-1)b = a+(p-1)\dfrac{c-d}{p-q} = c$,

$$\therefore \quad a = c - \frac{(p-1)(c-d)}{p-q} = \frac{d(p-1)-c(q-1)}{p-q}.$$

Hence, a and b being known, the whole series may be written down.

EXERCISE 137.

1. Find the 8th, 20th and $(n-3)$th terms of the series .

(i) 2, 4, 6, 8, &c (ii) 1, 3, 5, 7, &c. (iii) $\frac{13}{3}, \frac{7}{3}, \frac{1}{3}, -\frac{5}{3}$, &c

(iv) $\frac{9}{7}, \frac{5}{7}, \frac{1}{7}$, &c (v) 5, 11, 17, ..

2. What terms of the series 9, 11, 13, 15, &c, are 65, 99 and $6n-13$?

3. The first term of a given series is 3 and the 7th term 39, find the common difference

4. If there be 60 terms in A P of which the first term is 8 and the last term 185, find the 31st term

5. The 3rd and the 13th terms of a series in A P are -40 and 0 Find the series and determine its 20th term

6. The 5th and the 31st terms of an A P are 1 and -77 Obtain its 1st and 18th terms

7. Find the 1st term and the common difference of a series whose 8th and 102th terms are 23 and 305 respectively

8. The pth term of an A P is c and its qth term is d Find the rth term.

9. *If every term of an A P be increased or diminished by the same quantity, the resulting terms will also be in A P.*

10. Prove that *if each term of an A P be multiplied or divided by the same quantity, the resulting series will also be in A P*

11. If a be the first term and l the last term of a series of numbers in A P, show that the 5th term from the beginning + the 5th term from the end $=a+l$

12. In the preceding example show that the rth term from the beginning + the rth term from the end $=a+l$

13. Is 302 a term of the series 3, 8, 13, 18, &c ? [Here, the common difference $=5$ If possible, let $302=$ the rth term of the series, r being evidently an integer

$$\therefore \quad 302=3+(r-1)5, \text{ or, } r-1=\frac{302-3}{5}, \text{ or, } r=\frac{304}{5}.$$

The value of r being fractional is inadmissible

$\therefore$ 302 is not a term of the series]

14. The pth term of an A P is q and the qth term is p. Show that the mth terms is $p+q-m$

271. To find the sum of n terms of an Arithmetic series of which the first term is a and the common difference, b.

Let S denote the required sum, and l, the last term (*i e*, the nth term)

Then $S=a+(a+b)+(a+2b)+(a+3b)+\&c+\{a+(n-1)b\}$

And, by writing the series in the reverse order, we have also $S=l+(l-b)+(l-2b)+(l-3b)+\&c+\{l-(n-1)b\}$

Therefore, by addition,

$$2S=(a+l)+(a+l)+(a+l)+\&c \quad \text{to } n \text{ terms}=n(a+l),$$

$$\therefore \quad S=\frac{n}{2}(a+l) \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

Thus the sum of n terms in A P is n times the semi-sum of the first and last terms, or, in other words, n times the average of the first and last terms

Also, since $l=a+(n-1)b$

$$\therefore \quad S=\frac{n}{2}\left[a+\left\{a+(n-1)b\right\}\right]=\frac{n}{2}\left[2a+(n-1)b\right] \quad (2)$$

N B The formulæ (1) and (2) should be carefully remembered so that they might readily be applied in any suitable case

Example 1. Find the sum of 20 terms of the series 5, $4\frac{1}{3}$, $3\frac{2}{3}$, &c.

The first term $=5$, and the common diff $=\frac{13}{3}-5=-\frac{2}{3}$.

Hence, the required sum $=\frac{20}{2}\{2\times 5+(20-1)\times(-\frac{2}{3})\}$

$$=10(10-\tfrac{19\times 2}{3})=10(-\tfrac{8}{3})=-26\tfrac{2}{3}$$

Example 2. Find the value of $1+2+3+4+$ &c. to 100 terms.

The last term of the series evidently $=100$.

Hence, the required sum $=\frac{100}{2}(1+100)=50\times 101=5050$

Example 3. Find, without assuming any formula, the sum of $1+4+7+10+ \ldots +37$. [C U 1919]

Evidently, the common difference $=3$ and the number of terms in the series $=13$

Let S denote the required sum

$$\therefore\quad S=1+4+7+\ldots+31+34+37.$$

Also, re-writing the series in the reverse order,

$$S=37+34+31+\ldots+7+4+1.$$

Adding together the two series,

$$2S=38+38+\ldots \text{ to } 13 \text{ terms}=38\times 13\,;$$

$$\therefore\quad S=\frac{38\times 13}{2}=19\times 13=247.$$

Example 4. Find, without assuming any formula the sum of the series $1+3+5+7+\ldots$ to n terms. [C U 1911]

Evidently, the common difference $=2$

and the nth term $=1+(n-1)\times 2=2n-1$

Let $\quad S=$ the sum required

$$\therefore\quad S=1+3+5+\ldots+(2n-5)+(2n-3)+(2n-1).$$

Re-writing the series in the reverse order,

$$S=(2n-1)+(2n-3)+(2n-5)+\ldots+5+3+1.$$

Adding the two series,

$$2S=2n+2n+2n+\ldots \text{ to } n \text{ terms}=2n.n$$

$$\therefore\quad S=n^2.$$

EXERCISE 138.

Find the sum of the following series :

1. $1+2+3+4+ \ldots .$ &c to 25 terms

2. $1+3+5+7+ \ldots$ &c to 30 terms

3. $-3, 3, 9, 15, \ldots \ldots$ *to 14 terms*

4. $\frac{3}{5}+\frac{5}{5}+\frac{7}{5}+ \ldots$ to 20 terms

5. $\frac{7}{11}+\frac{13}{22}+\frac{6}{11}+ \ldots$ to 30 terms

6. $1\frac{1}{7}+1+\frac{6}{7}+\frac{5}{7}+ \ldots$ to 16 terms

7. $3+4+8+9+13+14+18+19 \ldots$ to 20 terms.

[C. F A 1881]

[The given series $=(3+4)+(8+9)+(13+14)+(18+19)+ \ldots$

$=7+17+27+37+ \quad$ to 10 terms

$=\frac{\{14+(10-1)\times 10\}}{2}\times 10=520$]

8. $5+4\frac{3}{4}+4\frac{1}{2}+ \ldots$ &c to 21 terms

9. $13+12\frac{1}{3}+11\frac{2}{3}+ \ldots$ &c to 40 terms

10. $2+7+12+ \ldots$ &c to 101 terms

11. $\frac{n-1}{n}+\frac{n-2}{n}+\frac{n-3}{n}+$ &c to n terms

12. $\frac{a-b}{a+b}+\frac{3a-2b}{a+b}+\frac{5a-3b}{a+b}+$ &c to n terms

13. $1+5+3+9+5+13+7+17+ \ldots$ to 30 terms

14. $\left(2-\frac{1}{n}\right)+\left(2-\frac{3}{n}\right)+\left(2-\frac{5}{n}\right)+$ to n terms

15. $(a+b)^2+(a^2+b^2)+(a-b)^2+$ to n terms.

Find the sum of the following series without applying any formula :

16. $3+5+7+ \ldots$ to 29 terms

17. $-10-6-2+2+$ to 22 terms

18. $(x-y)+(2x-3y)+(3x-5y)+ \ldots$ to n terms.

19. $5+8+11+\ldots+155$.

20. $8+3-2-7-12$ to n terms

272. Applications of the formulæ (1) and (2) of the preceding article. The following examples will illustrate some important applications of those formulæ.

Example 1. The first term of a series in A P is 17, the last term $-12\frac{3}{8}$ and the sum $25\frac{7}{16}$; find the common difference.

Let n = the number of terms . then we must have

$$25\frac{7}{16}=\frac{n}{2}\left\{17+\left(2-1\frac{3}{8}\right)\right\}=\frac{n}{2}\left(17-12\frac{3}{8}\right)=\frac{n}{2}\times 4\frac{5}{8},$$

$$\text{or,}\qquad \frac{407}{16}=\frac{37n}{16};\ \therefore\ n=\frac{407}{37}=11.$$

If, then, b be the required common difference, we must have $-12\frac{3}{8}(=\text{the 11th term})=17+10b$,

$$\therefore\quad 10b=-12\tfrac{3}{8}-17=-29\tfrac{3}{8}=-\tfrac{235}{8};$$

$$\therefore\quad b=-\frac{235}{8\times 10}=-\frac{5\times 47}{5\times 2\times 8}=-\frac{47}{16}.$$

Example 2. The sum of a series in A P is 72, the first term 17, and the common difference -2, find the number of terms. and explain the double answer

Let n = the number of terms

Then we must have

$$72=\frac{n}{2}\{2\times 17+(n-1)\times(-2)\}$$

$$=\frac{n}{2}\{34-2(n-1)\}=\frac{n}{2}(36-2n)=18n-n^2;$$

$$\therefore\quad n^2-18n+72=0,\ \text{ or, } (n-6)(n-12)=0;$$

$$\therefore\quad n=6, \text{ or, } 12$$

The double answer shows that there are two sets of numbers, satisfying the conditions of the problem, and this can be easily verified For, the series to 6 terms is 17, 15, 13, 11, 9, 7, and to 12 terms it is 17, 15, 13, 11, 9, 7 5, 3, 1,

$-1, -3, -5$, now since the sum of the last 6 terms of the latter set of numbers $=0$, evidently therefore the sum of 6 terms of the series, is exactly the same as that of 12 terms

Example 3. How many terms of the series $-8, -6, -4$, &c amount to 52 ?

Let $\quad n=$ the required number

Then we must have

$$52=\frac{n}{2}\{2\times(-8)+(n-1)\times 2\}$$

$$=\frac{n}{2}(2n-18)=n^2-9n\ ,$$

$$\therefore\quad n^2-9n-52=0\ ,$$

or, $\quad (n-13)(n+4)=0\ ;$

$$\therefore\quad n=13,\ \text{or},\ -4$$

Hence, since the number of terms can only be a positive integer, we must reject the negative value and take 13 to be the answer to the question

Example 4. The sum of p terms of an A.P. is q and the sum of q terms is p, find the sum of $p+q$ terms

Let a be the first term, and b the common difference ; then since the sum of p terms $=q$, we must have

$$q=\frac{p}{2}\{2a+(p-1)b\},$$

or, $\quad 2q=p\,2a+p(p-1)b \quad \dots \quad \dots \quad (1)$

Similarly, $\quad 2p=q\,2a+q(q-1)b \quad \dots \quad (2)$

Subtracting (2) from (1) we have

$$2(q-p)=(p-q)\,2a+\{(p^2-q^2)-(p-q)\}b$$

$$=(p-q)\,2a+(p-q)(p+q-1)b\ ;$$

$$\therefore\quad -2=2a+(p+q-1)b$$

Hence, the sum of $(p+q)$ terms

$$=\frac{p+q}{2}\{2a+(p+q-1)b\}$$

$$=\frac{p+q}{2}\times(-2)=-(p+q)$$

EXERCISE 139.

1. The first term of an A. P is 5, the number of terms 30, and their sum 1455; find the common difference

2. The first term of a series being 2, and the 5th term being 7, find how many terms must be taken so that the sum may be 63

3. What is the common difference when the first term is 1, the last 50, and the sum 204?

4. How many terms of the series 19, 17, 15, &c, amount to 91?

5. The sum of a certain number of terms of the series 21, 19, 17, &c is 120 Find the last term and the number of terms

6. How many terms of the series 54, 51, 48, &c, must be taken to make 513? Explain the double answer

7. If the sum of 8 terms of an A P is 64, and the sum of 19 terms is 361, find the sum of n terms.

8. Find the series of which the nth term is $\frac{3+n}{4}$; and also find the sum of the series to 105 terms

9. Find the series whose rth term is $2r-1$; find the sum of the series to n terms.

10. The sum of n terms of an A. P. is $3n^2-n$, and the common difference 6, find the first term

11. The sum of n terms of an A.P. is 40, the common difference 2, and the last term 13, find n.

12. Prove that the latter half of $2n$ terms of any arithmetical series $=\frac{1}{3}$ of the sum of $3n$ terms of the same series.

13. If $2n+1$ terms of the series 1, 3, 5, 7, 9, &c. be taken, then the sum of the alternate terms 1, 5, 9, &c, will be to the sum of the remaining terms 3, 7, 11, &c, as $n+1$ is to n

14. Prove that (i) $b=\dfrac{l^2-a^2}{2s-(l+a)}$,

and (ii) $s=\dfrac{l+a}{2b}(l-a+b)$

273. Arithmetic means.

Definition 1. When three quantities are in Arithmetic Progression the middle one is said to be the **Arithmetic mean** between the *other two*

Thus 5 is the Arithmetic mean between 3 and 7

Definition 2. If A and B be any two quantities and x_1, x_2, x_3, x_4, &c, x_{n-1}, x_n a number of others such that A, x_1, x_2, x_3, &c, x_{n-1}, x_n, B are in Arithmetical Progression, then x_1, x_2, x_3, &c are called the **Arithmetic means** between A and B

Thus 3, 4, 5, 6, 7 are Arithmetic means between 2 and 8, and so are the numbers $3\frac{1}{2}$, 5 and $6\frac{1}{2}$; for both the series 2, 3, 4, 5, 6, 7, 8 and 2, $3\frac{1}{2}$, 5, $6\frac{1}{2}$, 8 are in A P

Note *It is evident from the above example that between any two quantities the number of different sets of Arithmetic means is unlimited*

274. To insert a given number of Arithmetic means between two given quantities.

Let a and c be the two given quantities, and n the number of means to be inserted

Then we have to find out n quantities x_1, x_2, x_3, &c, x_{n-2}, x_{n-1}, x_n such that a, x_1, x_2, x_3, &c, x_{n-1}, x_n, c may be in A P Evidently the series $[a, x_1, x_2, x_3$, &c, $x_{n-1}, x_n, c]$ consists of $n+2$ terms of which a is the first term and c the last

Hence, if b be the common difference, we must have

$$c=a+(n+1)b,$$

whence $$b=\frac{c-a}{n+1}.$$

Hence, $$x_1=a+b=a+\frac{c-a}{n+1}$$

$$x_2=a+2b=a+\frac{2(c-a)}{n+1}$$

&c &c &c

$$x_n=a+nb=a+\frac{n(c-a)}{n+1}.$$

Example 1. Find the Arithmetic mean between any two quantities a and b

Let x=the quantity sought.

Then a, x b are in A P ,

and $\therefore$ we must have $x-a=b-x$,

$$\text{whence } x=\frac{a+b}{2}.$$

Example 2. Insert 4 Arithmetic means between 3 and 18.

Let x_1, x_2, x_3, x_4 be the means.

Then 3, x_1, x_2, x_3, x_4, 13 are in A.P

Hence, if b=the common difference,

we must have $18=3+5b$; $\therefore$ $b=3$.

Hence
$$\left.\begin{aligned} x_1&=3+\ b=\ 6\\ x_2&=3+2b=\ 9\\ x_3&=3+3b=12\\ x_4&=3+4b=15 \end{aligned}\right\}$$

Thus the required means are 6, 9, 12 and 15.

EXERCISE 140.

1. Find the Arithmetic means between (i) 5 and 8; (ii) -5 and 21; (iii) $m-n$ and $m+n$; (iv) $(a+x)^2$ and $(a-x)^2$

2. Insert 2 Arithmetic means between (i) 8 and 12; (ii) -6 and 14

3. Insert 3 Arithmetic means between 117 and 477.

4. Insert 4 Arithmetic means between 2 and -18.

5. Insert 17 Arithmetic means between $3\frac{1}{2}$ and $-41\frac{1}{2}$.

6. There are n Arithmetic means between 1 and 31, such that the 7th mean : $(n-1)$th mean=5 : 9, required n.

275. The Natural Numbers. The numbers 1, 2, 3, &c are called the **natural numbers.**

(i) To find the sum of the first n natural numbers.

Let S denote the sum ; then

$$S = 1+2+3+ \ldots +n$$
$$= \frac{n}{2}(1+n) = \frac{n(n+1)}{2} \quad \ldots \quad \ldots \quad (A)$$

(ii) To find the sum of the first n odd natural numbers.

Let S denote the sum , then

$$S = 1+3+5+7+ \ldots \text{ to } n \text{ terms}$$
$$= \frac{n}{2}\{2+(n-1)\times 2\}$$
$$= \frac{n}{2}\times 2n = n^2 \quad \ldots \quad \ldots \quad (B)$$

(iii) To find the sum of the squares of the first n natural numbers.

Let S denote the sum , then

$$S = 1^2+2^2+3^2+4^2+ \ldots +n^2.$$

We have, $n^3-(n-1)^3 = 3n^2-3n+1$

Hence, putting 1, 2, 3, &c , for n, we have

$$1^3-0^3 = 3\cdot 1^2 - 3\cdot 1+1,$$
$$2^3-1^3 = 3\cdot 2^2 - 3\cdot 2+1,$$
$$3^3-2^3 = 3\cdot 3^2 - 3\cdot 3+1,$$
$$4^3-3^3 = 3\cdot 4^2 - 3\cdot 4+1,$$
$$\ldots \quad \ldots \quad \ldots$$
$$(n-1)^3-(n-2)^3 = 3(n-1)^2-3(n-1)+1$$
$$n^3-(n-1)^3 = 3n^2-3n+1$$

Hence, by addition,

$$n^3 = 3(1^2+2^2+3^2+ \ldots +n^2) - 3(1+2+3+ \ldots +n) + n$$
$$= 3S - 3\,\frac{n(n+1)}{2} + n \,;$$
$$\therefore \quad 3S = n^3 - n + \frac{3n(n+1)}{2}$$
$$= n(n+1)\{(n-1)+\tfrac{3}{2}\} \,;$$
$$\therefore \quad S = \frac{n(n+1)(2n+1)}{6}. \quad \ldots \quad \ldots \quad \ldots \quad (C)$$

(iv) To find the sum of the cubes of the first n natural numbers.

Let S denote the sum; then

$$S=1^3+2^3+3^3+ \qquad +n^3.$$

We have, $n^4-(n-1)^4=4n^3-6n^2+4n-1.$

Hence, putting 1, 2, 3, &c, for n, we have

$$1^4-0^4=4.1^3-6.1^2+4.1-1,$$
$$2^4-1^4=4.2^3-6.2^2+4.2-1,$$
$$3^4-2^4=4.3^3-6.3^2+4.3-1,$$
$$\cdots \qquad \cdots \qquad \cdots$$
$$(n-1)^4-(n-2)^4=4(n-1)^3-6(n-1)^2+4(n-1)-1,$$
$$n^4-(n-1)^4=4n^3-6n^2+4n-1.$$

Hence, by addition,

$$n^4=4(1^3+2^3+3^3+\&c+n^3)-6(1^2+2^2+3^2+\&c+n^2)$$
$$+4(1+2+3+\&c.+n)-n$$

$$=4S-6\frac{n(n+1)(2n+1)}{6}+4.\frac{n(n+1)}{2}-n;$$

$$\therefore\ 4S=n^4+n+n(n+1)(2n+1)-2n(n+1)$$
$$=n(n+1)\{(n^2-n+1)+(2n+1)-2\}$$
$$=n(n+1)(n^2+n);$$

$$\therefore\quad S=\frac{n^2(n+1)^2}{4}=\left\{\frac{n(n+1)}{2}\right\}^2. \qquad \ldots (D)$$

Thus, *the sum of the cubes of the first n natural numbers is equal to the squares of the sum of these numbers.*

Example 1. Sum the series $1.2+2.3+3.4+$&c to n terms

The nth term of the series evidently$=n(n+1)=n^2+n$

Hence, putting $n=1$, the 1st term$=1^2+1$,

„ „ $n=2$, „ 2nd term$=2^2+2$,

„ „ $n=3$, „ 3rd term$=3^2+3$.

... ...

and so on

Hence, if S denote the sum of the given series, we have

$$S=(1^2+1)+(2^2+2)+(3^2+3)+\&c \text{ to } n \text{ terms}$$
$$=(1^2+2^2+3^2+\&c+n^2)+(1+2+3+\&c+n)$$
$$=\frac{n(n+1)(2n+1)}{6}+\frac{n(n+1)}{2}$$
$$=\frac{n(n+1)}{2}\left\{\frac{2n+1}{3}+1\right\}=\frac{n(n+1)(n+2)}{3}.$$

Example 2. Sum the series—

$$1^2+3^2+5^2+7^2+\&c \text{ to } n \text{ terms.}$$

Since evidently each term of the given series is equal to the square of the *corresponding* term of the series 1, 3, 5, 7, &c, ∴ the nth term of the given series = the square of the nth term of the series 1, 3, 5, 7, &c ,

and ∴ the nth term $=\{1+(n-1)\times 2\}^2$

$$=(2n-1)^2$$
$$=4n^2-4n+1$$

Hence, putting $n=1, 2, 3$, &c , we have

the 1st term $=4\cdot1^2-4\cdot1+1$,
" 2nd " $=4\cdot2^2-4\cdot2+1$,
" 3rd " $=4\cdot3^2-4\cdot3+1$,
... ...
and so on.

Hence, if S denote the sum of the given series, we must have

$$S=4(1^2+2^2+3^2+\&c+n^2)-4(1+2+3+\&c.+n)+n$$
$$=4\,\frac{n(n+1)(2n+1)}{6}-4\,\frac{n(n+1)}{2}+n$$
$$=2n(n+1)\left\{\frac{(2n+1)}{3}-1\right\}+n$$
$$=\frac{2n(n+1)\times 2(n-1)}{3}+n$$
$$=\frac{n}{3}\{4(n^2-1)+3\}=\frac{n}{3}(4n^2-1)$$

Example 3. Sum the series—

$$1^2+(1^2+2^2)+(1^2+2^2+3^2)+\&c \text{ to } n \text{ terms}$$

The nth term of the given series—

$$=1^2+2^2+3^2+\&c+n^2$$

$$=\frac{n(n+1)(2n+1)}{6}=\frac{n(2n^2+3n+1)}{6}$$

$$=\tfrac{1}{3}n^3+\tfrac{1}{2}n^2+\tfrac{1}{6}n.$$

Hence, the 1st term $=\frac{1}{3}1^3+\frac{1}{2}1^2+\frac{1}{6}1,$

" 2nd " $=\frac{1}{3}2^3+\frac{1}{2}2^2+\frac{1}{6}2,$

" 3rd " $=\frac{1}{3}3^3+\frac{1}{2}3^2+\frac{1}{6}3,$

... ...

and so on

Hence, if S denote the required sum, we must have

$$S=\tfrac{1}{3}(1^3+2^3+3^3+\&c+n^3)$$
$$+\tfrac{1}{2}(1^2+2^2+3^2+\&c+n^2)+\tfrac{1}{6}(1+2+3+\&c+n)$$
$$=\frac{1}{3}\cdot\frac{n^2(n+1)^2}{4}+\frac{1}{2}\cdot\frac{n(n+1)(2n+1)}{6}+\frac{1}{6}\cdot\frac{n(n+1)}{2}$$
$$=\frac{n(n+1)}{12}\{n(n+1)+(2n+1)+1\}$$
$$=\frac{n(n+1)}{12}(n^2+3n+2)=\frac{n(n+1)^2(n+2)}{12}.$$

EXERCISE 141.

Sum the series

1. $2^2+5^2+8^2+\&c$ to n terms

2. $1.2^2+2.3^2+3.4^2+\&c.$ to n terms

3. $1.3+3.5+5.7+7.9+\&c$ to n terms

4. $1^3+3^3+5^3+\&c.$ to n terms

5. $1+(1+2)+(1+2+3)+\&c.$ to n terms

6. $(1)+(1+3)+(1+3+5)+\&c$ to n terms.

7. $1.2.3+2.3.4+3.4.5+$ to n terms.

8. $2.3.1+3.4.4+4.5.7+\&c$ to n terms

9. $1-2+3-4+5-6+\&c$ to n terms

10. $1^2-2^2+3^2-4^2+5^2-6^2+\&c$. to n terms.

276. Miscellaneous Examples and Problems.

Example 1. Prove that if the number of terms of an A P be *odd*, twice the middle term is equal to the sum of the first and the last terms

Since the number of terms is odd, let it be denoted by $2n+1$

Evidently the middle term is one which has n terms on either side of it, hence it is the $(n+1)$th term from the beginning and also the $(n+1)$th term from the end

Hence, putting M for the middle term, we must have

$$M=a+(\overline{n+1}-1)b$$
$$=a+nb \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

and also
$$M=l-(\overline{n+1}-1)b$$
$$=l-nb \quad \ldots \quad . \quad \ldots \quad (2)$$

Hence, by addition,

$$2M=a+l$$

Example 2. Prove that the sum of an odd number of terms in A P is equal to the middle term multiplied by the number of terms

Let $2n+1=$ the number of terms.

Then the sum of the terms

$$=\frac{2n+1}{2}(a+l)=\frac{2n+1}{2}\times 2M \quad \text{[last example]}$$
$$=(2n+1)\times M$$

Example 3. Find the first five terms of the series of which the sum to n terms$=5n^2+3n$.

Let t_1, t_2, t_3, &c, t_n denote respectively the 1st, 2nd, 3rd, &c, nth terms of the series,

and let s_1, s_2, s_3, &c, s_n denote respectively the sums of 1, 2, 3, &c, n terms of the series

Evidently then $s_1=t_1$; $s_2=t_1+t_2$, $s_3=t_1+t_2+t_3$, and so on

Now, by the question, we have

$$s_n=5n^2+3n$$

(i e, the sum of *any number* of terms = 5 times the square of *that number* + 3 times *that number*)

Hence, putting $n=1$, we have $s_1=5+3=8$,

" $n=2$, " $s_2=20+6=26$,

" $n=3$, " $s_3=45+9=54$,

" $n=4$, " $s_4=80+12=92$,

" $n=5$, " $s_5=125+15=140$,

and so on

Hence,

$$t_1=s_1=8,$$
$$t_2=s_2-s_1=\ 26-\ 8=18,$$
$$t_3=s_3-s_2=\ 54-26=28,$$
$$t_4=s_4-s_3=\ 92-54=38,$$
$$t_5=s_5-s_4=140-92=48,$$

and so on

Thus the first five terms of the series are 8, 18, 28, 38 and 48

Example 4. Sum the series—

$$1+5+12+22+35+\&c \text{ to } n \text{ terms.}$$

[The peculiarity of the series is that the successive differences of the terms are in A P]

Let S denote the required sum and let t_n denote the nth term of the series Then we have

$$S=1+5+12+22+\quad +t_n;$$

also $$S=0+1+5+12+\quad +t_{n-1}+t_n$$

Hence, by subtraction,

$$0=1+4+7+10+\&c+(t_n-t_{n-1})-t_n$$
$$=\{1+4+7+10+\&c. \text{ to } n \text{ terms}\}-t_n;$$

$$\therefore\ t_n=\frac{n}{2}\{2+(n-1)3\}=\frac{n(3n-1)}{2},$$

i.e, the nth term of the given series $=\frac{3}{2}n^2-\frac{1}{2}n$

Hence, the 1st term $=\frac{3}{2}1^2-\frac{1}{2}1$,

2nd " $=\frac{3}{2}2^2-\frac{1}{2}2$,

3rd " $=\frac{3}{2}3^2-\frac{1}{2}3$,

and so on.

Hence, $S=\frac{3}{2}(1^2+2^2+3^2+\&c+n^2)-\frac{1}{2}(1+2+3+\&c+n)$

$$=\frac{3}{2}\cdot\frac{n(n+1)(2n+1)}{6}-\frac{1}{2}\cdot\frac{n(n+1)}{2}$$

$$=\frac{n(n+1)}{4}2n=\frac{n^2(n+1)}{2}.$$

Example 5. Sum the series $\frac{1}{1\,2}+\frac{1}{2\,3}+\frac{1}{3\,4}+\&c$ to n terms

Let S denote the sum to n terms

Now, we have

$$t_1=\frac{1}{1\,2}=1-\frac{1}{2},$$

$$t_2=\frac{1}{2.3}=\frac{1}{2}-\frac{1}{3},$$

$$t_3=\frac{1}{3\,4}=\frac{1}{3}-\frac{1}{4},$$

$$\&c, \quad \&c, \quad \&c,$$

$$t_n=\frac{1}{n(n+1)}=\frac{1}{n}-\frac{1}{n+1}.$$

Hence $$S=1-\frac{1}{n+1}=\frac{n}{n+1}.$$

Example 6. Divide 15 into three parts which are in A.P. and whose product $=120$

Let $\alpha-\beta$, α and $\alpha+\beta$ be the numbers,

then we have

$$\left.\begin{aligned} &(\alpha-\beta)\,\alpha\,(\alpha+\beta)=120 && (1)\\ \text{and}\quad &(\alpha-\beta)+\alpha+(\alpha+\beta)=15 && (2)\end{aligned}\right\}$$

From (2), $3\alpha=15$, $\alpha=5$

From (1), $\alpha(\alpha^2-\beta^2)=120$,

$5(25-\beta^2)=120$,

$25-\beta^2=24$,

$\beta^2=1 \quad \therefore \beta=\pm1$.

Hence the numbers are 4, 5, 6

Example 7. If a^2, b^2, c^2 be in A. P., then

$$\frac{1}{b+c}, \frac{1}{c+a}, \frac{1}{a+b} \text{ are in A P}$$

Evidently $\frac{1}{b+c}, \frac{1}{c+a}, \frac{1}{a+b}$ are in A P,

$$\text{if } \frac{1}{c+a}-\frac{1}{b+c}=\frac{1}{a+b}-\frac{1}{c+a},$$

$$\text{i e, if } \frac{b-a}{(c+a)(b+c)}=\frac{c-b}{(a+b)(c+a)},$$

$$\text{i e, if } (b-a)(b+a)=(c-b)(c+b),$$

$$\text{i e, if } b^2-a^2=c^2-b^2;$$

but this is true by hypothesis,

$$\therefore \frac{1}{b+c}, \frac{1}{c+a}, \frac{1}{a+b} \text{ are in A P}$$

Example 8. If a, b and c be respectively the pth, qth and rth terms of an A P, prove that $a(q-r)+b(r-p)+c(p-q)=0$

Let α denote the first term and β the common difference of the A P, of which a, b and c are the pth, qth and rth terms; then we must have

$$\left.\begin{array}{ll} a=\alpha+(p-1)\beta & (1) \\ b=\alpha+(q-1)\beta & (2) \\ c=\alpha+(r-1)\beta & (3) \end{array}\right\}$$

Now we have to eliminate α and β from these three equations

Subtracting (2) from (1), and (3) from (2), we have

$$a-b=(p-q)\beta,$$

$$b-c=(q-r)\beta$$

Hence, $$(a-b)(q-r)=(b-c)(p-q),$$

$$\text{or, } a(q-r)+b(r-p)+c(p-q)=0$$

Example 9. A person lends Rs 1000 to a friend agreeing to charge no interest and also to recover the amount by monthly instalments decreasing successively by Rs 2 In

how many months will the loan be paid up, if the first instalment be Rs 64? [C U 1920]

Let n = the number of months required

the successive instalments are evidently in A P

whose 1st term = 64

and whose common difference = -2

Since the sum of the n instalments = Rs 1000

The sum of the 1st n terms of this A P = 1000

i e, $\frac{n}{2}\{2\times 64+(n-1)(-2)\}=1000,$

or, $(65n-n^2)=1000$

or, $n^2-65n+1000=0$

or, $(n-25)(n-40)=0$

Hence, $n=25$, or, 40

But n cannot be 40, since in that case the 40th instalment

= the 40th term of the A P

$=64+(-2)(40-1)=-14,$

which is inadmissible, as no instalment can be negative,

n must be 25

EXERCISE 142.

1. The $(n+1)$th term of a series in A P is $\dfrac{ma-nb}{a-b}$, required the sum of the series to $(2n+1)$ terms

2. Find the first five terms of the series of which the sum to n terms is $2n^2+7n$

3. The sum to n terms of an A P is $3n^2+10n$, find the first term and the common difference

4. Find the 35th term of the series of which the sum to n terms is n^2+n

5. Sum the series—

$1+3+6+10+15+$ &c, to n terms

6. Sum the series—

$$2+5+10+17+\&c, \text{ to } n \text{ terms}$$

7. Sum the series—

$$2+7+14+23+34+\&c, \text{ to } n \text{ terms}$$

8. Sum the series—

(i) $\dfrac{1}{3\,5}+\dfrac{1}{5\,7}+\dfrac{1}{7\,9}+\&c$ to n terms

(ii) $\dfrac{1}{a(a+b)}+\dfrac{1}{(a+b)(a+2b)}$

$$+\frac{1}{(a+2b)(a+3b)}+\&c \qquad \text{to } n \text{ terms.}$$

9. Find 4 numbers in A P, such that their sum shall be 56, and the sum of their squares 864

[Let $\alpha-3\beta$, $\alpha-\beta$, $\alpha+\beta$ and $\alpha+3\beta$ be the numbers.]

10. The sum of three numbers in A P is 15, and the sum of the squares of the two extremes is 58 What are the numbers?

11. There are four numbers in A P, the sum of the two extremes is 8, and the product of the means is 15 What are the numbers?

12. Find six numbers in A P, such that the sum of the two extremes may be 16 and the product of the two middle terms 63

[Let $\alpha-5\beta$, $\alpha-3\beta$, $\alpha-\beta$, $\alpha+\beta$, $\alpha+3\beta$, $\alpha+5\beta$ be the numbers.]

13. (i) If $(b-c)^2$, $(c-a)^2$, $(a-b)^2$ are in A P, show that

$$\frac{1}{b-c},\ \frac{1}{c-a},\ \frac{1}{a-b} \text{ are in A. P},$$

(ii) If a, b, c be in A P, show that

(1) $\dfrac{1}{bc}, \dfrac{1}{ca}, \dfrac{1}{ab}$ are in A P,

(2) $b+c, c+a, a+b$ are in A P.

(3) $a^2(b+c), b^2(c+a), c^2(a+b)$ are in A. P.

(4) $\dfrac{1}{a}\left(\dfrac{1}{b}+\dfrac{1}{c}\right), \dfrac{1}{b}\left(\dfrac{1}{c}+\dfrac{1}{a}\right), \dfrac{1}{c}\left(\dfrac{1}{a}+\dfrac{1}{b}\right)$ are in A P.

(5) $a\left(\frac{1}{b}+\frac{1}{c}\right)$, $b\left(\frac{1}{c}+\frac{1}{a}\right)$, $c\left(\frac{1}{a}+\frac{1}{b}\right)$ are in A P

14. If a, b and c be respectively the sums of p, q and r terms of an A P , prove that

$$\frac{a}{p}(q-r)+\frac{b}{q}(r-p)+\frac{c}{r}(p-q)=0$$

15. The pth term of an A P is a and the qth term b Show that the sum of the first $(p+q)$ terms is

$$\frac{p+q}{2}\left\{a+b+\frac{a-b}{p-q}\right\}.$$ [M U 1887]

[See Example 2, Art 270]

16. There are n Arithmetic means between 3 and 54. such that the 8th mean $:(n-2)$th mean$=3:5$, find n

17. If S_1, S_2, S_3 be the sums of n terms of three Arithmetic series, the first term of each being 1 and the respective common differences 1, 2 3 prove that $S_1+S_3=2S_2$

18. If there be r Arithmetic Progressions, each beginning from unity, whose common differences are 1, 2, 3, &c , r, show that the sum of their nth terms is$=\frac{1}{2}\{(n-1)r^2+(n+1)r\}$

19. Sum the series—

$$n\cdot1+(n-1)\cdot2+(n-2)\cdot3+(n-3)\cdot4+\&c+1\cdot n$$

[The rth term of the series$=\{n-(r-1)\}r=(n+1)r-r^2$ Hence, the required sum$=(n+1)\{1+2+3+\ldots+n\}-\{1^2+2^2+3^2+\ldots+n^2\}=$&c]

20. On the ground are placed n stones; the distance between the first and second is one yard, between the 2nd and 3rd three yards, between the 3rd and 4th five yards, and so on How far will a person have to travel who shall bring them, one by one, to a basket placed at the first stone ?

21. A class consists of a number of boys whose ages are in A P , the common difference being four months If the youngest boy is just eight years old, and if the sum of the ages is 168 years, find the number of boys in the class [C U 1872]

22. The interior angles of a rectilineal figure are in A P If the least angle is 42° and the common difference is 33°, find the number of sides

CHAPTER XXXVIII

GEOMETRICAL PROGRESSION

277. Definition. Quantities are said to be in Geometrical Progression when each is equal to the product of the preceding and some constant factor

The constant factor is called the **common ratio** of the series, and it is found by dividing *any* term by that which immediately *precedes it*

Thus each of the following series forms a Geometrical Progression

$$1, \quad 2, \quad 4, \quad 8, \quad 16 \quad \&c.$$
$$1, \quad \tfrac{1}{2}, \quad \tfrac{1}{4}, \quad \tfrac{1}{8}, \quad \tfrac{1}{16}, \quad \&c$$
$$1, \quad -\tfrac{1}{3}, \quad \tfrac{1}{9}, \quad -\tfrac{1}{27}, \quad \tfrac{1}{81}, \quad \&c$$
$$a, \quad ar, \quad ar^2, \quad ar^3, \quad ar^4, \quad \&c.$$

In the first example the common ratio is 2, in the second $\frac{1}{2}$, in the third $-\frac{1}{3}$, and in the fourth r.

N.B 'Geometrical Progression' is briefly written as **G. P.**

278. To find the *n*th term of a G. P.

If a be the first term and r the common ratio of a Geometric series, we have the 2nd term $= ar$, the 3rd term $= ar^2$, the 4th term $= ar^3$, the 10th term $= ar^9$, the 21st term $= ar^{20}$, and so on Hence, the nth term $= ar^{n-1}$

Example. Find the 6th term of the series 2, 6, 18, 54, &c

Here, $a=2$ and the common ratio $=\frac{6}{2}=3$

$\therefore$ The 6th term $=2\times(3)^{6-1}=486$.

279. Given any two terms of a G.P., to find the series completely.

Example 1. Find the G P whose 5th term is 81 and whose 8th term is 2187

Let $a=$ the 1st term

and $r=$ the common ratio

$\therefore \quad 81=ar^{5-1}=ar^4. \quad \ldots \quad (1)$

$$\text{and} \qquad 2187 = ar^{8-1} = ar^7$$

$$\text{Dividing,} \qquad r^3 = \tfrac{2187}{81} = 27,$$

$$\therefore \qquad r = 3$$

$$\text{Hence,} \qquad ar^4 = a\,3^4 = 81,$$

$$\text{or,} \qquad a = \frac{81}{3^4} = 1$$

Thus, the series is 1, 3, 9, 27, &c

Example 2 If c and d be the pth and qth terms respectively of a G P, to determine it completely

$$\text{Let} \qquad a = \text{the 1st term}$$

$$\text{and} \qquad r = \text{the common ratio,}$$

$$\therefore \qquad c = \text{the common of the G P}$$

$$= ar^{p-1} \qquad (1)$$

$$\text{Similarly,} \qquad d = ar^{q-1} \qquad (2)$$

$$\text{By division,} \quad r^{q-p} = \frac{d}{c};$$

$$r = \left(\frac{d}{c}\right)^{\frac{1}{q-p}}.$$

Substituting for r in (1), we have

$$a = \frac{c}{r^{p-1}} = \frac{c}{\left(\frac{d}{c}\right)^{\frac{p-1}{q-p}}} = \left(\frac{c^{q-1}}{d^{p-1}}\right)^{\frac{1}{q-p}}.$$

Hence, the 1st term and the common ratio being known, the complete series may be written down.

EXERCISE 143.

1. Find the 8th term of the series 4, 12, 36, &c

2. Find the 6th term of the series $3\frac{3}{8}, 2\frac{1}{4}, 1\frac{1}{2}$, &c

3. Find the 9th term of the series 1, 4, 16, 64, &c

4. Find the 6th term of the series $1, -3, 9, -27$, &c

5. Find the 5th term and the $(n-1)$th term of the series $\frac{3}{2}, -1, \frac{2}{3}$, &c

6. Find the 7th term of the series $-21, 14, -9\frac{1}{3}$. &c

7. The first two terms of a series in G P. are 125 and 25, what are the 6th and 7th terms ?

8. Find the series (i) whose 6th and 11th terms are respectively 192 and 6144, (ii) whose 2nd and 8th terms are 9 and $\frac{1}{81}$ respectively, (iii) whose 5th and 8th terms are 8 and $-\frac{64}{27}$ respectively

9. The pth and qth terms of a G P are c and d respectively Find the nth term

10. If every term of a G P is multiplied or divided by the same quantity, the resulting series is also a G P

11. In a G P, if the $(p+q)$th term $=m$ and the $(p-q)$th term $=n$, find the pth and qth terms [B U 1888]

12. In a G P prove that the product of any pair of terms equidistant from the beginning and the end is constant

280. To find the sum of a number of terms in Geometrical Progression.

Let a be the first term, r the common ratio, n the number of terms and S the sum required, then

$$S = a + ar + ar^2 + ar^3 + \&c + ar^{n-1},$$

$$\therefore \quad Sr = ar + ar^2 + ar^3 + \&c + ar^{n-1} + ar^n$$

Hence, by subtraction,

$$Sr - S = ar^n - a,$$

$$S(r-1) = a(r^n - 1),$$

$$S = \frac{a(r^n-1)}{r-1} \qquad (1)$$

$$\text{or,} \qquad = \frac{a(1-r^n)}{1-r}. \qquad (2)$$

Cor. If l denote the last (or the nth) term of the series, we have $l = ar^{n-1}$; hence from (1),

$$S = \frac{rl - a}{r-1} \qquad (3)$$

Note *The formula (2) may conveniently be used in all cases except when r is positive and greater than 1.*

Example 1. Find the sum of $\frac{16}{27} - \frac{8}{9} + \frac{4}{3} - \&c$, to 7 terms

The common ratio $= -\frac{8}{9} \div \frac{16}{27} = -\frac{8}{9} \times \frac{27}{16} = -\frac{3}{2}$

Hence by formula (2)

$$\text{the sum}=\frac{\frac{16}{27}\{1-(-\frac{3}{2})^7\}}{1+\frac{3}{2}}$$

$$=\frac{\frac{16}{27}\{1+\frac{2187}{128}\}}{\frac{5}{2}}=\frac{16}{27}\times\frac{2315}{128}\times\frac{2}{5}=\frac{463}{108}=4\frac{31}{108}.$$

Example 2. Find the sum of $3+4\frac{1}{2}+6\frac{3}{4}+$ &c to 5 terms

The common ratio $=4\frac{1}{2}\div3=\frac{9}{2}\times\frac{1}{3}=\frac{3}{2}$

Hence, if S denote the required sum, we have by formula (1),

$$S=\frac{3\{(\frac{3}{2})^5-1\}}{\frac{3}{2}-1}=\frac{3\{\frac{243}{32}-1\}}{\frac{1}{2}}=3\times\frac{211}{32}\times2$$

$$=\frac{633}{16}=39\frac{9}{16}$$

EXERCISE 144.

1. Sum $1+3+9+27+$ &c to 12 terms
2. Sum $81-27+9-$ &c, to 8 terms
3. Sum $2-4+8-$ &c, to 10 terms
4. Sum $\frac{4}{9}-\frac{1}{3}+\frac{1}{4}-$ &c, to 5 terms
5. Sum $2-4+8-$ &c, to $2r$ terms
6. Sum $2\frac{1}{2}-1+\frac{2}{5}-$ &c to n terms
7. Show that the sum of n terms of a G.P beginning with the pth term, is r^{p-q} times the sum of an equal number of terms of the same series beginning with the qth term

281. If n be an integer and r a given proper fraction, to prove that r^n diminishes as n increases.

Let $r=\frac{3}{7}$ Now, since $\frac{3}{7}$ of any number is undoubtedly less than that number,

$(\frac{3}{7})^2$ is less than $\frac{3}{7}$, because $(\frac{3}{7})^2=\frac{3}{7}$ of $\frac{3}{7}$,

$(\frac{3}{7})^3$ is less than $(\frac{3}{7})^2$, because $(\frac{3}{7})^3=\frac{3}{7}$ of $(\frac{3}{7})^2$,

$(\frac{3}{7})^4$ is less than $(\frac{3}{7})^3$, because $(\frac{3}{7})^4=\frac{3}{7}$ of $(\frac{3}{7})^3$,

and so on

Hence, it is clear that in the series $\frac{3}{7}$, $(\frac{3}{7})^2$, $(\frac{3}{7})^3$, $(\frac{3}{7})^4$, .. each term is less than the preceding, which is briefly expressed by saying that $(\frac{3}{7})^n$ diminishes as n increases

Similarly the proposition may be proved for any other value of r which is less than 1

Hence, generally speaking, if r has a given value less than 1, r^n diminishes as n increases

Note. *From the above it is quite clear that if r be a proper fraction, is very small when n is infinitely large*

282. The sum of a Geometrical series continued to infinity.

Let us consider the series a, ar, ar^2, ar^3, &c

If S denote the sum to n terms, we have

$$S=\frac{a(1-r^n)}{1-r}=\frac{a}{1-r}-\frac{ar^n}{1-r}.$$

If then r be a *proper fraction*, the larger n is, the smaller will (r^n and ∴) $\frac{ar^n}{1-r}$ be; hence by sufficiently increasing the value of n we can make $\frac{ar^n}{1-r}$ less than any assigned quantity, however small, and therefore by *sufficiently increasing the value of n, the sum of n terms of the series can be made to differ from* $\frac{a}{1-r}$ *by as small a quantity as we please*

This statement is usually put thus *the sum of an infinite number of terms of the Geometrical Progression is* $\frac{a}{1-r}$, or more briefly, *the sum to infinity is* $\frac{a}{1-r}$.

Let us apply all these remarks to a particular example

Consider the series $1, \frac{1}{2}, \frac{1}{4}, \frac{1}{8}$, &c

Here $a=1$, $r=\frac{1}{2}$; hence the sum to n terms

$$=\frac{1}{1-\frac{1}{2}}\left(1-\frac{1}{2^n}\right)=2\left(1-\frac{1}{2}\right)=2-\frac{1}{2^{n-1}}.$$

Now by taking n large enough, 2^{n-1} can be made as large as we please, and therefore $\frac{1}{2^{n-1}}$ as small as we please

Hence, we may say that *by taking n large enough, the sum of n terms of the series can be made to differ from 2 by as small a quantity as we please*, or briefly, *the sum of an infinite number of terms of this series is 2*

N B It must be borne in mind that the sum of n terms of a Geometrical Progression ***approaches a fixed limit as n increases indefinitely only when r is less than unity. If r be greater than unity there is no such fixed limit.***

Example 1. Prove that in a decreasing Geometrical Progression continued to infinity each term bears a constant ratio to the sum of all which follow it

Let the series be a, ar, ar^2, ar^3, &c, where r is less than unity

Then the n^{th} term $= ar^{n-1}$ and the sum of all the terms which follow this

$$= ar^n(1 + r + r^2 + r^3 + \&c, \text{ to infinity})$$

$$= ar^n \cdot \frac{1}{1-r}.$$

Hence, the ratio of the nth term to the sum of all which follow it

$$= \left(ar^{n-1} \div \frac{ar^n}{1-r}\right) = \frac{1-r}{r}.$$

Now this is constant *whatever value n may have*, which proves the proposition

Example 2. Sum to infinity $\frac{3}{2} - \frac{2}{3} + \frac{8}{27} - \&c$

Here $a = \frac{3}{2}$, and $r = -\frac{2}{3} \div \frac{3}{2} = -\frac{4}{9}$.

Hence, the required sum $= \dfrac{\frac{3}{2}}{1 + \frac{4}{9}}$

$$= \frac{3}{2} \times \frac{9}{13}$$

$$= \frac{27}{26}.$$

EXERCISE 145.

Sum to infinity each of the following series

1. $\frac{1}{2}+\frac{1}{4}+\frac{1}{8}+\frac{1}{16}+$ &c **2.** $1-\frac{1}{2}+\frac{1}{4}-\frac{1}{8}+$ &c

3. $\frac{5}{8}+\frac{1}{2}+\frac{2}{5}+\frac{8}{25}+$ &c **4.** $1-\frac{2}{3}+\frac{4}{9}-$ &c

5. $3\frac{3}{8}+2\frac{1}{4}+1\frac{1}{2}+$ &c

6. $\frac{2}{5}+\frac{3}{5^2}+\frac{2}{5^3}+\frac{3}{5^4}+$ &c [Split this up into two series]

7. $\frac{4}{7}+\frac{5}{7^2}+\frac{4}{7^3}+\frac{5}{7^4}+$ &c **8.** $\sqrt{3}+\frac{1}{\sqrt{3}}+\frac{1}{3\sqrt{3}}+$ &c

9. $(\sqrt{2}+1)+1+(\sqrt{2}-1)+$ &c

10. Find the common ratio of a G P, continued to infinity in which each term is ten times the sum of all the terms which follow it

283. Recurring Decimals. Recurring decimals furnish a good illustration of infinite Geometrical Progressions

Thus, for example, $234 = 234343434$.

$$= \left.\begin{array}{r} 2 \\ +\,034 \\ +\,00034 \\ +\,0000034 \\ +\,\&c,\ \&c \end{array}\right\} = \frac{2}{10}+\frac{34}{10^3}+\frac{34}{10^5}+\frac{34}{10^7}+\&c$$

Here the terms after $\frac{2}{10}$ constitute a G P, of which the first term is $\frac{34}{10^3}$ and the common ratio $\frac{1}{10^2}$.

Hence, we may take $'234=\frac{2}{10}+\frac{34}{10^3}\div\left\{1-\frac{1}{10^2}\right\}$

$=\frac{2}{10}+\frac{34}{990}=\frac{232}{990}$, which agrees with the value found by the usual Arithmetical rule

284. Geometric means. Definition 1. When three quantities are in Geometrical Progression the middle one is called the **Geometric mean** between the other two

Definition 2. When any number of quantities x_1 x_2 x_3, &c are such that a, x_1, x_2 x_3 &c b are in G P, then x_1 x_2, x_3 &c are called **Geometric means** between a and b

(i) To find the Geometric means between two given quantities

Let a and b be the two given quantities G the Geometric mean

Then since a G, b are in G P we must have $\frac{G}{a}=\frac{b}{G}$, each being equal to the common ratio

$$\therefore \quad G^2=ab \text{ and } \qquad G=\sqrt{ab}$$

(ii) To insert a given number of Geometric means between two given quantities

Let a and b be the two given quantities, and x_1 x_2 x_3, x_4, &c x_n the n means to be inserted.

Then a, x_1, x_2, x_3 &c x_n, b are in G.P

Let r denote the common ratio of the series

then b=the $(n+2)$th term$=ar^{n-1}$

$$r^{n-1}=\frac{b}{a},$$

$$\text{and} \;.. \qquad r=\left(\frac{b}{a}\right)^{\frac{1}{n-1}}$$

Hence $x_1=a\left(\frac{b}{a}\right)^{\frac{1}{n-1}}$ $x_2=a\left(\frac{b}{a}\right)^{\frac{2}{n-1}}$; $x_3=a\left(\frac{b}{a}\right)^{\frac{3}{n-1}}$ and so on

Example. Insert 3 Geometric means between $\frac{1}{2}$ and 128

Let x_1, x_2, x_3 be the means

Then, $\frac{1}{2}$ x_1 x_2 x_3, 128 are in G P

Hence, if r be the common ratio of the series we must have 128=the 5th term$=\frac{1}{2}r^4$

$$\therefore \quad r^4=256 \text{ whence } r=4$$

$$\text{Hence} \qquad \left.\begin{aligned} x_1&=\tfrac{1}{2}4 = 2 \\ x_2&=\tfrac{1}{2}4^2= 8 \\ x_3&=\tfrac{1}{2}4^3=32 \end{aligned}\right\}.$$

285. *The arithmetic mean of any two positive quantities is greater than their geometric mean*

Let a and b be two positive quantities

Their Arithmetic mean $=\dfrac{a+b}{2}$

and geometric mean $=\sqrt{ab}$

Now, $\dfrac{a+b}{2}-\sqrt{ab}$

$=\frac{1}{2}[a-2\sqrt{a}\sqrt{b}+b]$

$=\frac{1}{2}(\sqrt{a}-\sqrt{b})^2$

$=$ a positive quantity

$\therefore \quad \dfrac{a+b}{2}>\sqrt{ab}$

EXERCISE 146.

1. Insert 2 Geometric means between 3 and 24

2. Insert 3 Geometric means between $2\frac{1}{4}$ and $\frac{4}{9}$

3. Insert 4 Geometric means between $\frac{2}{3}$ and $-5\frac{1}{16}$

4. Insert 5 Geometric means between $3\frac{5}{9}$ and $40\frac{1}{2}$

5. If a, b and c be in G P and x, y be the arithmetic means between a, b and b, c respectively, prove that

$$\frac{a}{x}+\frac{c}{y}=2 \text{ and } \frac{1}{x}+\frac{1}{y}=\frac{2}{b}.$$ [P U 1892]

6. The Arithmetic mean of a and c is to their Geometric means as m to n, show that

$$a : b=m+\sqrt{m^2-n^2} : m-\sqrt{m^2-n^2}$$ [A U 1889]

7. If the arithmetic and geometric means of two quantities be respectively A and B, prove that the quantities are

$$A+\sqrt{A^2-B^2} \text{ and } A-\sqrt{A^2-B^2}$$

[Let the numbers be a and b Suppose $a>b$

$$\therefore \quad a+b=2A \qquad (1)$$

and $\sqrt{ab}=B$

Now, $(a-b)^2=(a+b)^2-4ab=4(A^2-B^2)$

or, $a-b=2\sqrt{A^2-B^2} \qquad (2)$

[taking the positive root, since $a>b$, i e $a-b$ is positive]

Adding (1) and (2), $2a=2A+2\sqrt{A^2-B^2}$

or, $a=A+\sqrt{A^2-B^2}$

Also, subtracting (2) from (1) $b=A-\sqrt{A^2-B^2}$]

286. Miscellaneous Series and Examples.

Example 1. If $x<1$, sum the series

$$1+2x+3x^2+4x^3+\&c, \text{ to infinity}$$

Let S denote the required sum , then

$$S=1+2x+3x^2+4x^3+\&c$$

and $\quad Sx= \quad x+2x^2+3x^3+\&c$

Hence, by subtraction,

$$S(1-x)=1+x+x^2+x^3+\&c \text{ to infinity}$$

$$=\frac{1}{1-x},$$

$$\therefore S=\frac{1}{(1-x)^2}.$$

Example 2. Sum to n terms $5+55+555+\&c$

Let S denote the required sum , then

$S=5+55+555+\&c$ to n terms

$=5\{1+11+111+\&c$ to n terms$\}$

$=\frac{5}{9}\times 9\{1+11+111+\&c$ to n terms$\}$

$=\frac{5}{9}\{9+99+999+\&c$ to n terms$\}$

$=\frac{5}{9}\{(10-1)+(10^2-1)+(10^3-1)+\&c$, to n terms$\}$

$=\frac{5}{9}\{(10+10^2+10^3+\&c$ to n terms$)-n\}$

$$=\frac{5}{9}\left\{\frac{10(10^n-1)}{10-1}-n\right\}=\frac{50}{81}\left(10^n-1\right)-\frac{5n}{9}.$$

Example 3. Sum to n terms $1+5+13+29+\&c$

Let t_n denote the nth term of the series, and S the required sum; then

$$S=1+5+13+29+\&c+t_n;$$

also $$S=0+1+5+13+\&c+t_{n-1}+t_n$$

Therefore, by subtraction,

$$0=(1+4+8+16+\&c.\text{ to } n \text{ terms})-t_n,$$

$$t_n=1+\{4+8+16+\&c\text{ to }(n-1)\text{ terms}\}$$

$$=1+\frac{4(2^{n-1}-1)}{2-1}$$

$$=1+2^2(2^{n-1}-1)=2^{n+1}-3$$

Hence, the 1st term $=2^2-3$.

" 2nd " $=2^3-3$

" 3rd " $=2^4-3$.

and so on

Hence $S=(2^2-3)+(2^3-3)+(2^4-3)+\&c+(2^{n+1}-3)$

$$=(2^2+2^3+2^4+\&c\text{ to } n \text{ terms})-3n$$

$$=\frac{2^2(2^n-1)}{2-1}-3n$$

$$=4(2^n-1)-3n$$

Example 4. If a, b, c, d be in G P, show that

$$(a-d)^2=(b-c)^2+(c-a)^2+(d-b)^2.$$

We have $\frac{b}{a}=\frac{c}{b}=\frac{d}{c}$, each of them being equal to the common ratio,

$$\therefore \quad b^2=ac,\ c^2=bd;\text{ and } bc=ad \qquad (a)$$

Hence, $(b-c)^2+(c-a)^2+(d-b)^2$
$=(b^2+c^2-2bc)+(c^2+a^2-2ca)+(d^2+b^2-2db)$
$=2(b^2-ac)+2(c^2-bd)+a^2+d^2-2bc$
$=2\times 0+2\times 0+a^2+d^2-2ad$ [by a]
$=(a-d)^2$

Example 5. If a, b, c, d be in G P, shew that
$a^2-b^2, b^2-c^2, c^2-d^2$ are in G P

Evidently $a^2-b^2, b^2-c^2, c^2-d^2$ are in G P
if $(a^2-b^2)(c^2-d^2)=(b^2-c^2)^2$

Now, since a, b, c, d are in G P, we have

$$\frac{b}{a}=\frac{c}{b}=\frac{d}{c};$$

$ac=b^2, \quad bd=c^2$ and $ad=bc$

Hence, $(a^2-b^2)(c^2-d^2)=a^2c^2-b^2c^2-a^2d^2+b^2d^2$
$=b^4-b^2c^2-b^2c^2+c^4$
$=b^4-2b^2c^2+c^4$
$=(b^2-c^2)^2$,
. $a^2-b^2, b^2-c^2, c^2-d^2$ are in G P

Example 6. The continued product of three numbers in G P is 216, and the sum of the products of them in pairs is 156; find the numbers

Let $\frac{a}{r}, a, ar$ be the numbers,

then, by the conditions given, we must have

$$\left.\begin{aligned} &\frac{a}{r}\,a\,ar = 216 \qquad (1) \\ \text{and } &\frac{a}{r}a+\frac{a}{r}ar + a\,ar = 156 \qquad (2) \end{aligned}\right\}$$

From (1) $a^3=216$ $a=6$.

Hence from (2), $\frac{1}{r}+1+r=\frac{156}{36}=\frac{13}{3}$,

$3(1+r+r^2)=13r$

or, $(3r^2-10r+3)=0,$

or, $(r-3)(3r-1)=0.$

$r=3$, or $\frac{1}{3}$

Hence, the numbers are 2, 6, 18

EXERCISE 147.

1. Find by the method of summation of infinite Geometric series the values of :

(i) 027; (ii) 1 145, (iii) 21501; (iv) $\dot{1}4285\dot{7}$

2. Sum $1+3x+5x^2+7x^3+$&c to infinity

3. Sum $1\ 2x+2\ 4x^2+3\ 8x^3+$&c to infinity

4. Sum $1\ 3x+4\ 9x^2+7\ 27x^3+$&c to infinity

5. Sum $a+2a^2+3a^3+4a^4+$&c to n terms

6. Sum $1-3x+5x^2-7x^3+$&c to infinity

7. Sum $\frac{1}{3}+\frac{3}{9}+\frac{5}{27}+$&c to infinity

8. Sum $1+\frac{2}{2}+\frac{3}{2^2}+\frac{4}{2^3}+$&c to n terms

9. Find the nth term, and the sum to n terms of the series

1 1, 2 3, 4 5, 8 7, &c

10. Sum $1+\frac{2}{5}+\frac{3}{5^2}+\frac{4}{5^3}+$&c to n terms

11. Sum to n terms $4+44+444+$&c

12. Sum the series $9+99+999+$&c to n terms

13. Sum the series $1+3+7+15+$&c to n terms

14. Sum to n terms $-6-4+0+8+24+$&c

15. Find the sum of $6+9+21+69+261+$&c to n terms

16. If a, b, c, d be in G P, shew that

$$(a^2+b^2+c^2)(b^2+c^2+d^2)=(ab+bc+cd)^2$$

[We have $\frac{a}{b}=\frac{b}{c}=\frac{c}{d}=k$ (say), thus $a=bk$, $b=ck$, $c=dk$, hence

$$a^2+b^2+c^2=k^2(b^2+c^2+d^2)$$

and also $$a^2+b^2+c^2=k(ab+bc+cd)\,]$$

17. If a, b, c, d are in G P, prove that

(i) $(b+c)(b+d)=(c+a)(c+d)$,

(ii) $(a+d)(b+c)-(a+c)(b+d)=(b-c)^2$

18. Three numbers whose sum is 15 are in A P if 1 4 and 19 be added to them respectively, the results are in G P Determine the numbers

[Let $\alpha-\beta$, α, $\alpha+\beta$ be the numbers]

19. Three numbers whose product is 512 are in G P, if 8 be added to the first and 6 to the second, the numbers are in A P Find the numbers

20. The sum of three quantities in G P is $24\frac{4}{5}$, and their product is 64 find them

21. If a, b, c be respectively the pth qth and rth terms of a Geometric series, prove that $a^{q-r}b^{r-p}c^{p-q}=1$

22. If a, b, c be in A P and $x, y\ z$ in G P prove that $x^{b-c}y^{c-a}z^{a-b}=1$.

23. If S be the sum, P the product and R the sum of the reciprocals of n terms in G P, prove that $P^2=\left(\frac{S}{R}\right)^n$.

24. Find the sum of n terms of the series, the rth term of which is $(2r+1)2^r$

25. If $A=1+r^a+r^{2a}+$ to infinity and $B=1+r^b+r^{2b}+$ to infinity prove that $r=\left(\frac{A-1}{A}\right)^{\frac{1}{a}}\left(\frac{B-1}{B}\right)^{\frac{1}{b}}$.

26. If there be n terms in G P, prove that the nth root of their product is equal to the square root of the product of the first and last terms

27. If n Geometrical means be found between two quantities a and c, show that their product will be $(ac)^{\frac{n}{2}}$

28. If a, b, c, d are in G P, shew that the reciprocals of a^2-b^2, b^2-c^2, c^2-d^2 are also in G P

29. If S_1, S_2, S_3, &c, S_n are the sums of infinite Geometric series, whose first terms are 1, 2, 3, &c., n, and whose common ratios are $\frac{1}{2}, \frac{1}{3}, \frac{1}{4}$, &c, $\frac{1}{n+1}$ respectively, prove that

$$S_1+S_2+S_3+\&c+S_n=\frac{n}{2}(n+3)$$

30. Find the sum of the infinite series—

$1+(1+a)r+(1+a+a^2)r^2+(1+a+a^2+a^3)r^3+\&c.$, r and a being proper fractions

ANSWERS

EXERCISE 1. [Pages 2—4]

1.	100	2.	10	3.	12 miles	4.	8 miles
5.	9	6.	12	7.	45 minutes	8.	15 minutes
9.	32	10.	$\frac{1}{64}$ $20\frac{1}{4}$	11.	5 sq yds	12.	7*s* 6*d*
13.	20	14.	9	15.	28	16.	4
17.	4480	18.	900	19.	1952	20.	720

EXERCISE 2. [Pages 9 10]

1.	34	2.	0	3.	4	4.	1	5.	$5\frac{1}{3}$
6.	$1\frac{1}{3}$	7.	6	8	4	9.	12	10.	8
11.	2	12.	$\frac{1}{2}$	13.	5	14.	80	15.	29
16.	325	17.	0	18.	14	19.	114	20.	4
21.	69	22.	19	23.	0	24.	325	25.	9

EXERCISE 3. [Pages 12 13]

1.	24	2.	$37\frac{1}{3}$	3.	4	4.	720	5.	$3\frac{1}{3}$
6.	$\frac{2}{3}$	7.	1	8.	40	9.	$\frac{2}{3}$	10.	$\frac{8}{9}$
11.	0	12.	50	13.	1	14.	75	15.	100
16.	200	17.	1520	18.	41 625	19.	22680	20.	845000

EXERCISE 4. [Pages 15, 16]

1.	4	2.	2	3.	6	4.	18	5.	8
6.	16	7.	32	8.	256	9.	11	10.	21
11.	11	12.	9	13.	3	14.	162	15.	18
16.	9	17.	0	18.	21	19.	23	20.	1
21.	93	22.	50	23.	9	24.	42	25.	51
26.	2805	27.	7	28.	171	29.	2401	30.	192
31.	1029	32.	1218	33.	48	34.	143	35.	18750
36.	16	37.	160	38.	78	39.	7	40.	2

EXERCISE 5. [Pages 19, 20]

1. A's loss = £100 2. -70 3. -25
4. -100 5. -30 6. $4, -3, 5$
7. $15, -10, -20, 30$ 8. $-15, 10, 20, -30$

EXERCISE 6. [Page 22]

1. -22 2. -18 3. $-31, -41$ 4. $-19.$
5. -1180 6. -222 7. -2034 8. 658
9. -7128 10. -220416417

EXERCISE 7. [Page 24]

1. 3 2. -5 3. -4 4. -47 5. $-14.$
6. -51 7. 16 8. -8 9. -32 10. 1

EXERCISE 8. [Pages 27—29]

1. $-x+y$ 2. $m^2+n^2+p^2$ 3. $c^2+a^2b-a^2$ 4. $2abc-3mnp^2.$
5. $2a^3b-9b^2c^2-2df$ 6. $-6x^4y-11xyz-10x^2y^2$
7. $4(a^2bc-b^2ca+c^2ab)$ 8. $-25x^3mn+16m^3nx$ 9. -14
10. -234 11. 92 12. 5 13. $177.$
14. -4653 15. -12015 16. $-6a+b-3c$ 17. $2x-z$
18. $2x^3+9x^2+7$ 19. $-a+2b-8d$ 20. $2x^2-3y^2.$
21. 153 22. -125 23. 200 24. 120 25. 400

EXERCISE 9. [Pages 30, 31]

1. -10 2. 10 3. -6 4. -22 5. 0
6. -291 7. -77 8. 83 9. 17 10. $177.$

EXERCISE 10. [Page 32]

1. $2a+3b-2c$ 2. $-3a+3b+4c$ 3. $3x+2y-3z$
4. $2m^2-2m-4$ 5. $2x^2+y^2-z^2$ 6. $3x^2-2y^2-7xy.$
7. $4a^2-7ab-b^2$ 8. $7bc-7c^2+10xy$ 9. $-x^3+x^2-x+2$
10. $-(x+2y)$ 11. $3x-4y+5z$ 12. $6-2m^2-5m$
13. $-(3a^2b+3ab^2)$ 14. $2a^2b^2$ 15. $3ab^2-3a^2b$

EXERCISE 11. [Pages 35 36]

1. $-4a+8b$ **2.** $7x-4y$ **3.** $-2x$ **4.** $-4a+2b$
5. $5a+2b$ **6.** $2b$ **7.** 6 **8.** 8 **9.** $-2a+7b$
10. 0 **11.** $-2x+5y+7z$ **12.** $-2c$ **13.** $15x-15y$
14. $8a-8b$ **15.** $11m-7n$ **16.** $6a-6b-18c$
17. $6x-6y-20z$ **18.** $x-y-13z$ **19.** $-3x-y-z$
20. $a-11b+17c$ **21.** $2x-12y+20z$ **22.** $5a-b+11c$
23. $x-3y+2z$ **24.** $11a-2b-16c$ **25.** $a-(b+c-d)$
$+(-m+n-x)+y-z$ **26** $a-\{b+c-d+m+(-n+x-y+z)\}$
27. $\{a-b-(c-d+m)\}-\{-n-(-x+y-z)\}$
28. $-\{-a-(-b-c)\}-\{-d-(-m+n)\}-\{x-(y-z)\}$

EXERCISE 12. [Page 37]

1. 15 **2.** 18 **3.** 36 **4.** -32 **5.** -45
6. -78 **7.** -24 **8.** -35 **9.** -45 **10.** 36
11. 60 **12.** 64

EXERCISE 13. [Pages 38, 39]

1. 54 **2.** 47 **3.** -8 **4.** -393 **5.** -111
6. 30 **7.** 0 **8.** 1136 **9.** -280

EXERCISE 15. [Page 44]

14. $-6x^7y^5$ **15.** $21a^3b^4c^3$ **16.** $40x^{17}y^{16}$
17. $-156x^{10}y^9z^6$ **18** $140x^6y^7z^{20}$ **19.** $-4x^{11}y^7$
20. $-70a^{15}b^{12}$ **21.** $48x^{16}y^{10}z^7$ **22.** $24x^7y^8z^7$

EXERCISE 16. [Page 45]

1. $-10x^7$ **2.** $-20a^4b^6$ **3.** $21m^7n^8$ **4.** $-18x^4y^7$
5. $3a^7b^{10}$ **6.** $-40m^8n^7$ **7.** $50x^2y^3z^3$ **8.** $-24x^4y^4z^4$
9. $48x^5y^5z^5$ **10.** $25a^5b^9c^{13}$ **11.** $-24x^3y^3z^5$
12. $32a^3b^2x^2y^3$ **13.** $35a^3b^3z^4$ **14.** $-60a^6x^7y^5$
15. $70x^5y^5z$ **16.** $-18a^8b^6c^6$ **17.** $63a^9x^8y^2$
18. $160x^{14}y^7z^7$ **19.** $65a^{10}b^{14}c^{20}$ **20.** $112a^{13}x^{10}y^9z^7$

EXERCISE 17. [Pages 47, 48]

1. $xy-2x^2$ **2.** $-5a^2+10ab-15ac$ **3.** $8x^2y-12xy^2$
4. $2a^3bc-3ab^3c-abc^3$ **5.** $-3x^3y^2+6x^2y^3+3xy^4$
6. $7a^2b^3-7ab^4+21a^2b^4-35a^3b^2$ **7.** $-6a^4x+8a^3x^2-10a^3x$
8. $-8m^4n+12m^3n^2-20m^2n^3$ **9.** $a^2b^3c^2-a^3b^2c^2-a^2b^2c^3$
10. $x^3yz+xy^3z+xyz^3-xy^2z^2-x^2yz^2-x^2y^2z$ **11.** $12c^4d^5$
$-18c^3d^7+30c^3d^6+24c^4d^6$ **12.** $-16a^7b^3+12a^6b^4-10a^5b^5$
$+8a^4b^6$ **13.** $7x^4-2x^2$ **14.** 0 **15.** $9x^6-25y^4$ **16.** x^6+4x^2
17. $a^{12}b^6+4a^4b^2$ **18.** $4a^{18}b^{12}+81a^6b^4$ **19.** $3a^2y$
20. (i) $x^3+y^3+z^3-3xyz$, (ii) 0

EXERCISE 18. [Page 51]

1. $-4x^3$ **2.** $-3x^4$ **3.** $4a^4x^3$. **4.** $3x^5y^5$
5. $2a^2b^2$ **6.** $-2p^2q^2$ **7.** $5x^6y^4z$ **8.** $-8a^3c^2$
9. $-3m^5n^6p$ **10.** $3a^2c^2$ **11.** $-5x^4y^2$ **12.** $3a^6x^5y^4z^2$
13. a^{44} **14.** $-7x^{48}$ **15.** $-7m^{18}$ **16.** $-7a^{41}b^{120}$

EXERCISE 19. [Page 52]

1. $3a-2b$ **2.** $3b^2-2a^2$ **3.** $2a^2-3b^2$ **4.** $3x^2-4xy$
5. $3y^2-2x^2$ **6.** $n^2-3mn+4m^2$ **7.** $ax-2x^2+3a^2$
8. $-3x^2+2a^2-5ax$ **9.** $2m^2n^2-3m^4-4n^4$
10. $-p^2+\frac{5}{8}pq+\frac{3}{8}q^2$ **11.** $-2xy^2+3x^3-4y^3$
12. $\frac{3}{4}x^3-\frac{3}{2}a^3-\frac{9}{4}a^2x$ **13.** $3xa+\frac{15}{4}a^2-4x^2$
14. $5m^4n^2-7m^2n^4-8p^6$
15. $b^2c^2x^2y^2-2a^2c^2y^2z^2+3a^2b^2x^2z^2$

Miscellaneous Exercises. I.

[Pages 53—58]

I.

1. 10, $\frac{1}{2}$ **2.** 8. **3.** 15, $2a$; $7ab^2$, $16m^2pq$
4. 6 **5.** $-\frac{1}{2}$ **8.** 9, 7, 5, 2, -1, -3, -4, -8, -12

II

1\. 0 25, 46, 45 2. 16 3. $(\sqrt[3]{a})\times(\sqrt[3]{a})\times(\sqrt[3]{a})=a$, &c , 35
5\. $-7x^2y$, -560 6. $16x^4-8xy^3+24x^2y^2+y^4-32x^3y$; 81
7\. $-23a+30b+13c$ 8. $x-2y+z$

III

1\. (i) $c(a+b)=x-yz$, (ii) $(x+y)^2=x^2+y^2+2xy$,
(iii) $\sqrt[3]{m-n}-m^3n^3 < \sqrt{x}+\sqrt{y}$, (iv) $a > b$, $3a > 3b$
2\. $5, -4, -\frac{13}{2}, \frac{13}{2}, -10$ 3. -1000 5. 66
7\. $-6a^2+bc-9x^2+16$ 8. a

IV

1\. -11, 1 3. $4\frac{13}{15}$ 5. 9 6. $3x+2a+b$
7\. $a^2+b^2+c^2$ 8. $7x^2-y^2-2xy$

V.

3\. $2, a, b, a+b$ 4. $7\frac{1}{2}$ 5. 505 7. y 8. 32

VI

2\. 536 6. 60 8. 3808

VII

2\. 2 , 0 4. $1+x$, $3a+b-5c$ 5. (i) $(a+b)(a-b)=a^2-b^2$,
(ii) $(a+b)^2-(a^2+b^2)=2ab$ 6. 0 7. $a+b+c$
8\. $2a-\frac{3}{4}b+\frac{7}{8}c-\frac{3}{10}d$

VIII

2\. $2m$, $2n$ 3. $ma+mb+na+nb$, $a^2+2ab+b^2$ 4. 0 , 0
6\. $\frac{1}{x}+\frac{1}{y}+\frac{1}{z}$. 7. $36a^8b^{15}c^{22}x^{10}y^{10}z^{10}+90a^{13}b^{20}c^{12}x^8y^8z^8$
$+10a^{18}b^{10}c^{17}x^6y^6z^6$ 8. $2b^5c^{10}x^4y^2+5a^5b^{10}x^2z^4+3a^{10}c^5y^4z^2$

EXERCISE 20. [Page 60]

1\. $x^2+8x+16$ 2. $9a^2+12a+4$ 3. $x^2+4xy+4y^2$
4\. $4x^2+28xy+49y^2$ 5. $9a^2+24ab+16b^2$ 6. $25a^2+70ab+49b^2$

7. $a^2y^2+6abxy+9b^2x^2$ 8. $a^4+4a^2bc+4b^2c^2$
9. $9x^4+12x^2y^2+4y^4$ 10. $16x^4+8x^2y^3+y^6$
11. $a^2+4b^2+9c^2+4ab+6ac+12bc$ 12. $a^2b^2+b^2c^2+c^2a^2+2ab^2c+2a^2bc+2abc^2$ 13. $4p^2+9q^2+16r^2+12pq+16pr+24qr$
14. $x^4+y^4+z^4+2x^2y^2+2x^2z^2+2y^2z^2$
15. $4x^2+9y^2+16z^2+12xy+16xz+24yz$
16. $x^4+y^6+z^8+2x^2y^3+2x^2z^4+2y^3z^4$ 17. $x^2+y^2+4a^2+9b^2+2xy+4xa+6xb+4ya+6yb+12ab$ 18. $9a^2+16b^2+c^2+4d^2+24ab+6ac+12ad+8bc+16bd+4cd$ 19. $4a^2+x^2+16y^2+9z^2+4ax+16ay+12az+8xy+6xz+24yz$
20. $16m^2+9n^2+9p^2+4q^2+24mn+24mp+16mq+18np+12nq+12pq$ 21. $4x^2$ 22. $4z^2$ 23. $16a^2$ 24. $a^2+4ab+4b^2$
25. $x^2+2xy+y^2$ 26. 1 27. 0 28. 4 29. 9
30. 1 31. 16 32. 25

EXERCISE 21. [Pages 62, 63]

1. x^2-6x+9 2. $4x^2-20x+25$ 3. $9x^2-30xy+25y^2$.
4. $a^2x^2-2abxy+b^2y^2$ 5. $64m^2-48mn+9n^2$ 6. $p^2m^2-2pqmn+q^2n^2$ 7. $p^4-2p^2mn+m^2n^2$ 8. $x^4y^2-2x^3y^3+x^2y^4$ 9. $x^6-4x^4z+4x^2z^2$ 10. $9a^6-30a^3b^3+25b^6$
11. $x^2y^2z^2+2abcxyz+a^2b^2c^2$ 12. $x^4y^2z^2-2x^3y^3z^2+x^2y^4z^2$
13. $a^4x^8-2a^2b^2x^4y^4+b^4y^8$ 14. $a^2+4b^2+4c^2-4ab-4ac+8bc$ 15. $4x^2+9y^2+16z^2-12xy-16xz+24yz$. 16. $9m^2+16n^2+25q^2-24mn-30mq+40nq$ 17. $a^4+9b^4+25c^4-6a^2b^2-10a^2c^2+30b^2c^2$ 18. $x^2+y^2+a^2+b^2-2xy-2xa-2xb+2ya+2yb+2ab$ 19. $a^2+4x^2+9b^2+16y^2-4ax-6ab-8ay+12xb+16xy+24by$ 20. 7921 21. 13689
22. 218004 23. 986049 24. $36b^2$ 25. $64b^2$
26. $49a^2$ 27. $121z^4$ 28. $25b^2c^2+10bc^2a+c^2a^2$
29. 4 30. 81 31. 16 32. 25 33. 144

EXERCISE 22. [Pages 64, 65]

1. x^2-9 2. $25x^2-169$ 3. x^2-4a^2 4. $a^2x^2-b^2y^2$.
5. $a^2m^2-n^4$ 6. $x^2y^2-y^2z^2$ 7. $x^4-4y^2z^2$ 8. $x^2y^4-x^4y^2$ 9. x^4-1 10. a^8-b^8 11. $a^2+2ab+b^2-c^2$

12. $a^2-b^2-2bc-c^2$ **13.** $m^4+m^2n^2+n^4$ **14.** x^4+4y^4
15. $a^2x^2-b^2y^2+2bcyz-c^2z^2$ **16.** $b^2y^2+c^2z^2-a^2x^2+2bcyz$
17. $b^4m^2-c^4n^2-a^4p^2+2c^2a^2np$ **18.** $a^6-64b^6-729c^6$
$+432b^3c^3$ **19.** a^4x^4+4 **20.** $a^8x^8+a^4x^4+1$ **21.** m^4+n^4
22. x^8-1 **23.** $4a(b-c)$ **24.** $4a(3c-2b)$ **25.** $4xy(x^2+y^2)$
26. $4x(y-a+b)$ **27.** $8a(3b-5c+7d)$ **28.** 9376
29. 1069840 **30.** 4985645 **31.** $(5x+6)(5x-6)$
32. $(3a+4c)(3a-4c)$ **33.** $(4m+7n)(4m-7n)$ **34.** $(2p+9q)$
$(2p-9q)$ **35.** $(ax+8b)(ax-8b)$ **36.** $(6x^2+11y^2)(6x^2-11y^2)$
37. $(7+8d)(7-8d)$ **38.** $(12c+5d)(12c-5d)$ **39.** $(a+b+c)$
$(a+b-c)$ **40.** $(a+2b+5c)(a+2b-5c)$ **41.** $(2x+3a-4b)$
$(2x-3a+4b)$ **42.** $(a+2b-3c)(a-2b+3c)$. **43.** (a^2+9b^2)
$(a+3b)(a-3b)$ **44.** $(x-y+a-b)(x-y-a+b)$ **45.** $(9x^2+25y^2)$
$(3x+5y)(3x-5y)$ **46.** $(7a-b)(a+15b)$ **47.** $(5x-2y)(x+12y)$.
48. $(2a+3b-4c)(b-2c)$ **49.** $(2m+5n-2p)(2m+n-8p)$
50. $(5x-7y+12z)(x-y+2z)$

EXERCISE 23. [Page 67]

1. $x^3+9x^2+27x+27$ **2.** $8x^3+12x^2+6x+1$ **3.** $27a^3$
$+27a^2b+9ab^2+b^3$ **4.** $64x^3+144x^2y+108xy^2+27y^3$
5. $x^6+6x^4y+12x^2y^2+8y^3$ **6.** $x^3y^3+3x^2y^3z+3xy^3z^2+y^3z^3$
7 $a^6b^3+3a^4b^2c^2d+3a^2bc^4d^2+c^6d^3$ **8.** $a^3+b^3+8c^3+3a^2b$
$+3ab^2+6a^2c+12ac^2+6b^2c+12bc^2+12abc$ **9.** $8x^3+27y^3+z^3$
$+36x^2y+54xy^2+12x^2z+6xz^2+27y^2z+9yz^2+36xyz$ **10** x^9
$+3x^6y^3+3x^3y^6+y^9$ **11.** $125m^3$ **12.** $x^3+3x^2y+3xy^2+y^3$
13. $27b^3$ **14.** x^3+3x^2+3x+1 **15.** $x^3+6x^2+12x+8$ **16.** $8a^3$
17. 90 **18.** 175 **20.** 52 **21.** 0 **22** -1 **23.** 0 **24.** 10

EXERCISE 24. [Pages 68, 69]

1. $x^3-6x^2+12x-8$ **2.** $8x^3-12x^2+6x-1$ **3** $8-36a$
$+54a^2-27a^3$ **4.** $27-108a+144a^2-64a^3$ **5** $8a^3-36a^2b$
$+54ab^2-27b^3$ **6.** $125m^3-300m^2n+240mn^2-64n^3$ **7** $8x^3$
$-60x^2y+150xy^2-125y^3$ **8** $8a^3-b^3-c^3-12a^2b+6ab^2$
$-12a^2c+6ac^2-3b^2c-3bc^2+12abc$

9. $8x^3-27y^3-z^3-36x^2y+54xy^2-12x^2z+6xz^2-27y^2z-9yz^2+36xyz$ **10.** $p^6-q^6-r^6-3p^4q^2+3p^2q^4-3p^4r^2+3p^2r^4-3q^4r^2-3q^2r^4+6p^2q^2r^2$ **11.** $64b^3$ **12.** $x^3-3x^2y+3xy^2-y^3$ **13.** $8x^3$ **14.** 0 **15.** 343 **16.** -505 **17.** 27 **18.** 36 **19.** 140

EXERCISE 25. [Page 70]

1. x^3+1 **2.** $1+8x^3$ **3.** $125p^3+1$ **4.** $343a^3+64b^3$ **5.** $512x^3+27y^3$ **6.** $a^3b^3+64c^3$ **7.** $a^3x^3+125b^3$ **8.** $125a^3+729b^3$ **9.** $(a+1)(a^2-a+1)$ **10.** $(x+2)(x^2-2x+4)$ **11.** $(2x+1)(4x^2-2x+1)$ **12.** $(3a+2)(9a^2-6a+4)$ **13.** $(2m+4)(4m^2-8m+16)$ **14.** $(4p+5)(16p^2-20p+25)$ **15.** $(2x+6y)(4x^2-12xy+36y^2)$ **16.** $(3a+7y)(9a^2-21ay+49y^2)$ **17.** $(6ax+y)(36a^2x^2-6axy+y^2)$ **18.** $(3ab+4xy)(9a^2b^2-12abxy+16x^2y^2)$ **19.** $(9abc+10xyz)(81a^2b^2c^2-90abcxyz+100x^2y^2z^2)$ **20.** $(11ab^2x^3+9cy^2z^3)(121a^2b^4x^6-99ab^2cx^3y^2z^3+81c^2y^4z^6)$

EXERCISE 26. [Page 71]

1. $1-8x^3$ **2.** x^3-27 **3.** $64a^3-1$ **4.** $x^6-8y^3z^3$ **5.** $27m^3-8n^3q^3$ **6.** $(5a-1)(25a^2+5a+1)$ **7.** $(7x-2y^2)(49x^2+14xy^2+4y^4)$ **8.** $(6k-5l)(36k^2+30kl+25l^2)$ **9.** $(1-8k)(1+8k+64k^2)$ **10.** $(9m-4an^2)(81m^2+36man^2+16a^2n^4)$

EXERCISE 27. [Pages 72, 73]

1. x^2+3x+2 **2.** $x^2+11x+18$ **3.** x^2+x-30
4. $x^2-14x+33$ **5.** $a^2+5a-176$ **6.** $m^2+12m-133$
7. $p^2+2p-143$ **8.** $p^2-5p-204$ **9.** $x^2+5x-36$
10. $x^2-15x+50$ **11.** $x^2-7x-60$ **12.** $k^2-11k-26$
13. $a^2+19a+70$ **14.** $m^2-8m-84$ **15.** $x^2-18x+65$
16. $x^2+19x+84$ **17.** $a^2-14a+33$ **18.** $x^2-9x-52$
19. $m^2-11m-80$ **20.** $x^2-18x+80$ **21.** $a^2-6a-72$
22. $m^2+6m-91$ **23.** $x^2-26x+160$ **24.** $x^2-13x-90$
25. $x^2-6x-160$

EXERCISE 28. [Page 77]

1. 4 **2.** -5 **3.** -4 **4.** -5 **5.** -5 **6.** -60
7. 13 **8.** 5 **9.** -2 **10.** -2 **11.** 1 **12.** 2

13. 3 **14.** -4 **15.** 0. **16.** 7 **17.** -2. **18.** -1.
19. 7. **20.** 3 **21.** 5 **22.** 7. **23.** -6 **24** 0
25. -8 **26.** 9 **27.** -2. **28.** $\frac{1}{3}$ **29.** 1 **30** -1.
31. 12 **32.** 30 **33.** 12

EXERCISE 29. [Pages 79, 80]

1. $15-x$. **2.** $x-20$ **3.** $x+25$ **4.** $25-y$
5. $y-2x$ **6.** $\frac{21}{x}$. **7.** $100-3x$ **8.** $4x-3y$.
9. xy **10.** $\frac{x}{y}$ hours **11.** $(x+20)$ years, $(x-3)$ years
12. $\frac{60}{x}$ miles **13.** $\frac{44}{x}$ **14.** $\frac{7x}{4}$ rupees **15.** $x-2, x-1,$
$x, x+1, x+2$ **16.** $3x$ **17.** $2m+3$ **18** $2x-2$
19. $\frac{10x}{y}$ days **20.** $3ab$ **21.** $\frac{3ab}{16}$. **22.** $\frac{x}{3y}$.
23. $\frac{16a}{x}$ hours **24.** $(x+15)$ years $(x+45)$ years
25. $10y+x$ **26.** $100x+10y+z$ **27.** $100z+10y+x$

EXERCISE 30. [Pages 81, 82]

1. 6 feet and 3 feet **2.** 20 **3.** 40 and 10 **4.** 80
5. 12 **6.** 60 **7.** 40 **8.** 96 **9.** 42, 43 44 **10.** 33.
11. 25, 65 **12.** 15 and 24 **13.** 36 **14.** 72 **15.** 10 11.
16. £600, £250 **17.** £120, £300 **18.** £3 10*s* **19.** 35, 25
20. 30, 10

EXERCISE 31. [Page 86]

2. Take BE equal to AD, by guess let F be the middle point of DE Then F is very approximately the middle point of AB, the error, if any being indefinitely small

7. 2 56, 1 68, 3 79, 2 39, 1 40

EXERCISE 32. [Pages 89, 90]

1. $6\frac{2}{3}$ units of length **2.** $7\frac{4}{5}$ feet **3.** $7\frac{1}{7}$ yards.
4. 3 5 inches **5.** 3 6 feet **6.** $\frac{7}{10}$ feet **7.** 5 yards
8. 65 feet **9.** 17 feet **10.** 28 3 feet

EXERCISE 34. [Pages 97—99]

1. (i) (11 8), (−9 11), (−5, −6), (9, −10)
(ii) (2 2, 1·6), (−1 8, 2 2), (−1, −1 2), (1 8 −2)
2. $(3\frac{2}{3}, 2\frac{2}{3})$, $(-3, 3\frac{2}{3})$ $(-1\frac{2}{3}, -2)$, $(3\ -3\frac{1}{7})$ **5.** 20
6. 13 **7.** 50 **8.** 11 −13 **9.** 17 5, 36 **10.** 12, 8
11. 12 5 units of area **12.** 16 units of area **13.** 1 units of area **14.** 40 units of area, 7, 4 5 **15.** (i) 83, (ii) 78, (iii) 420, (iv) 72 **16.** 30 sq cm, 5 cm 90° **17.** 2 5 cm
18. 6, 7 **19** 5 **20.** 32 units of area, 7, 5

Miscellaneous Exercises. II.

[Pages 99—101]

I

1. $x^2+y^2+z^2-2xy+2yz-2zx$ **7.** $m^2+n^2+9p^2+2mn+3np+3pm$ **8.** $27x^2-93xy-66y^2$ **9.** 217

II

1. −4 **2.** −1 **3.** 3 **4.** $\frac{b^2}{a}$. **5.** $\frac{m^2+n^2+p^2}{mnp}$. **6.** 7
7. 11 **8.** 5 **9.** [illegible] **10.** $1\frac{1}{17}$

III

1. 7 **2.** 126 **3.** Rs 1500 **4.** £2250, £900, £750 £300
5. 40, 20, 36 **6.** £52, £2 12*s*

EXERCISE 35. [Pages 106—108]

1. $-5x^2-2xy-y^2-2x-y-2$ **2** $4a^2b$ **3.** $-m^3n^2-mnp-m^2n^2$ **3.** $a^2b^2x^2$ **5.** $a^4b^4c^4$ **6.** $a^3b^3-b^3c^3+c^3a^3-a^2b^2c^2$ **7.** $a^3+b^3+c^3-3abc$ **8.** $2(x+y+z)$ **9.** $2(x+y+z)$
10. $x^2y+y^2z+z^2x$ **11.** $a^2b+b^2c+c^2a+ab^2+bc^2+ca^2$
12. $abc^2+bca^2+cab^2+a^2d+b^2d+c^2d$ **13.** $-\frac{3}{4}(x+y+z)$
14. $-\frac{5}{14}(x+y+z)$ **15.** 0 **16.** 0 **17.** 0 **18.** 1280
19. 1280 **20.** 0 **21.** $(a^2+b^2)(m+n+p+q+l)+(a^2-b^2)(m+n+p+q+k)+c^2(l+m+n)$ **22.** $4(ax^2+by^2+cz^2)$ **23.** 0
24. $3(a^2+b^2+c^2-ab-bc-ca)$ **25.** $(a+b+c)(x^2+y^2+z^2)$

EXERCISE 36. [Pages 110—112]

1. $10x^5-11x^4y+10x^3y^2+6x^2y^3-3y^4$ **2** $2m^3nx-7n^3xm+12x^3mn+7m^2n^2x+8n^2x^2m$ **3.** $11x^6-3x^5y-50x^4y^2+15x^3y^3+26x^2y^4-19xy^5+40y^6$ **4.** $5ax^4-8a^2x^3+8yzbc^2+2y^2zbc+4yz^2bc$ **5.** $-2-x^3y^5z+2xy^3z^5+2x^3z^5y+6x^2y^2z^2-3xyz^4$ **6.** $4x^4y^3z^2-80x^3y^4z^2+28x^2y^3z^4-22x^3y^2z^4-102x^4y^2z^3+155x^2y^4z^3$ **7.** $-12x^3y^4z^5-100x^3y^5z^4+58x^4y^5z^3+92x^4y^3z^5+39x^5y^3z^4-38x^5y^4z^3$ **8.** $-4x^2+5xy-7y^2-8yz$ **9.** $6x^3-12x^2y^2+2a^2bx-7xby^2-9xyab$ **10.** $-2x^4+6x^3y-2x^2y^2+8xy^3+7y^4$ **11.** $-2x^5+3x^4y-10x^3y^2-4x^2y^3-13xy^4+50y^5$ **12.** $a^2+5ab-8b^2$ **13.** $4x^2-8xy+y^2-12x-15y+9$ **14.** $2a^3-4a^2b+7ab^2-15b^3$ **15.** $-12x^3y+7x^2y^2-8x^2+17y-29$ **16.** $5a^2-4ab-5bc+11b^2$ **17.** $-2x^3-3y^2-5xy-3x-2$ **18.** $-3a^3-11b^2c-6ac^2-5b^3$ **19.** $-4x^3-22xy^2-45y^3-11x^2-24xy-15$ **20.** $\frac{11}{24}x+\frac{19}{166}y+\frac{496}{57}z$ **21.** $\frac{9}{10}ax+\frac{11}{56}y+\frac{32}{45}mz$ **22.** $1{\cdot}2a^2cx+30{\cdot}08c^2by+{\cdot}45c^3z$ **23.** $-\frac{129}{38}a^{\frac{1}{2}}c^{\frac{3}{2}}x-\frac{15}{44}a^{\frac{1}{2}}b^{\frac{5}{4}}y-b^{\frac{3}{5}}c^{\frac{5}{12}}z+lx-6my-5nz$ **24.** (i) $1{\cdot}2x+2{\cdot}3y-6z$, (ii) $3{\cdot}5x-2{\cdot}47y-\frac{1}{21}z$, (iii) $3{\cdot}4a+19{\cdot}04l^2+20m^2+30p$ **25.** $2(bc^2+ca^2+ab^2)$ **26.** 0 **27.** 0 **28.** $ax+by+cz$ **29.** $2ax+12by-cz$ **30.** $14x+44y+7z$

EXERCISE 37. [Page 114]

1. $2a^2+5ab+3b^2$ **2.** $2m^2-5mn+3n^2$ **3.** $a^2+b^2+c^2+2ab+2ac+2bc$ **4.** $a^2+b^2+c^2-2ab+2ac-2bc$ **5.** $a^2+b^2+c^2-2ab-2ac+2bc$ **6.** $2a^2+2b^2+3c^2-5ab-7ac+5bc$ **7.** $2x^2+3y^2+4z^2-5xy-6xz+7yz$ **8.** $5x^2-2a^2-3b^2+3xa-2xb+5ab$ **9.** $x^3-y^3-z^3-x^2y-x^2z+xy^2-y^2z+xz^2-z^2y$ **10.** $x^2y^2-y^2z^2-z^2x^2-2yz^2x$

EXERCISE 38. [Pages 118—121]

1. $27a^3-75ab^2+45a^2b-125b^3$ **2** $4a^2-9b^2+24bc-16c^2$ **3.** x^4+3x^2+4 **4.** $a^4-2a^2b^2+b^4$ **5.** x^8+x^4+1

6. $x^6-x^4y^4+2x^3y^3+y^6$ **7.** m^6+n^6 **8.** p^6-q^6 **9.** $a^5-26a^3b^2+25ab^4$ **10.** $x^5-5x^3+5x^2-1$ **11.** $x^6-2a^3x^3+a^6$
12. $a^6-3a^4b^2+3a^2b^4-b^6$ **13.** $x^6+10x-33$ **14.** x^6-2x^3+1
15. $a^8+a^6b^2+a^4b^4+a^2b^6+b^8$ **16.** $x^3+y^3+z^3-3xyz$
17. $a^3+b^3+c^3-3abc$ **18.** $2a^6-a^5b-14a^4b^2+13a^3b^3-43a^2b^4+23ab^5-20b^6$ **19.** $apx^3+(bp-aq)x^2-(cp+bq)x+cq$
20. $mnx^3-(n^2+mr)x^2+r^2$ **21.** $ax^4-(1+a)bx^3+(c+b^2-ac)x^2-c^2$ **22.** $abx^5-(b^2+ac)x^4+(2bc+ad)x^3-(2bd+c^2)x^2+2cdx-d^2$ **23.** $mpx^4-(mq-mr+np)x^3+(ms+nq-mr-ps)x^2+(q-r-n)sx-s^2$ **24.** $alx^3+(2hl+am)x^2y+(bl+2hm)xy^2+bmy^3+anx^2+2hnxy+bny^2$ **25.** $l^2px^4+m^2px^3y+n^2px^2y^2+(l^2q+2g^2p)x^3+(m^2q+2f^2p)x^2y+n^2qxy^2+(c^2p+2g^2q+l^2r)x^2+(m^2r+2f^2q)xy+n^2ry^2+(2g^2r+c^2q)x+2f^2ry+c^2r$
26. $x^5+1\frac{766}{945}x^4y+3\frac{239}{945}x^3y^2+2\frac{356}{735}x^2y^3+2\frac{4}{35}xy^4+y^5$ **27.** $x^6+1\frac{2}{3}x^5y+3\frac{3}{11}x^4y^2+\frac{26}{33}x^3y^3+4\frac{16}{33}x^2y^4+\frac{1}{11}xy^5+y^6$ **28.** $621x^{12}+3{\cdot}197x^{10}+20{\cdot}7x^9+405x^8+{\cdot}3321x^7+2{\cdot}085x^6+16{\cdot}0872x^5+11{\cdot}07x^4+5{\cdot}8675x^3+29{\cdot}25x^2+6{\cdot}95x+45$ **29.** $399a^5+7{\cdot}289a^4b+16{\cdot}71a^3b^2+32{\cdot}867a^2b^3+23{\cdot}789ab^4+25{\cdot}2b^5$ **30.** $2{\cdot}3lx^5+(3{\cdot}15l+2{\cdot}3m)x^4y+(1{\cdot}17l+3{\cdot}15m+2{\cdot}3n)x^3y^2+(2{\cdot}07l+1{\cdot}17m+3{\cdot}15n)x^2y^3+(2{\cdot}07m+1{\cdot}17n)xy^4+2{\cdot}07ny^5$ **31.** $a^2x^5-\frac{29}{210}abx^4y+(\frac{181}{90}ac-b^2)x^3y^2+(\frac{55}{756}bc+\frac{4}{5}ad)x^2y^3+(c^2-\frac{6}{7}bd)xy^4+\frac{8}{9}cdy^5$
32. $2{\cdot}25a^2m^6+(3{\cdot}9ac-1{\cdot}44b^2)m^4n^2-(3{\cdot}84bd-1{\cdot}69c^2)m^2n^4-2{\cdot}56d^2n^6$ **33.** $16a^4-81b^4$ **34.** $625a^4x^4-1296b^4y^4$
35. $x^{12}-y^{12}$ **36.** $x^8+49x^4y^4+625y^8$ **37.** $a^{18}x^{18}-b^{18}y^{18}$

51. $-6x^2$ **52.** $-2y^4$ **53.** $6x^2y$ **54.** $15x^{\frac{5}{3}}y^{\frac{1}{4}}$.
55. $-3ab^{-2}$ **56.** $-ay^{-1}$ **57.** $12a^2b^2c^2$ **58.** $15xyz$
59. $-30a^2bc^{-1}$ **60.** $76a^{\frac{4}{3}}x^{-\frac{7}{8}}y^{-2}$ **61.** $a+2a^{\frac{1}{2}}b^{\frac{1}{2}}+b$
62. $a-2a^{\frac{1}{2}}b^{\frac{1}{2}}+b$ **63.** $9x^{\frac{4}{3}}-16y^{\frac{2}{3}}$ **64.** $a+b$
65. $x-y$ **66.** $a^3+a^{\frac{3}{2}}b^{\frac{3}{2}}+b^3$. **67.** $4x^{\frac{8}{3}}-37x^{\frac{4}{3}}y^{\frac{4}{3}}+9y^{\frac{8}{3}}$
68. a^3-b^2 **69.** x^2-y^2 **70.** $a-b^2$

71. $x+y+z-3x^{\frac{1}{3}}y^{\frac{1}{3}}z^{\frac{1}{3}}$ **72.** $a^{3n}+x^{3n}$

73. $a^{-5}-6a^{-4}b+13a^{-3}b^2-13a^{-2}b^3+6a^{-1}b^4-b^5$

74. $x^{-6}-5x^{-3}y^3+4y^6$ **75.** $4a^{-10}+12a^{-\frac{15}{2}}b^{-\frac{3}{2}}+9a^{-5}b^{-3}$
$-25b^{-6}$ **76.** $6x^3+19x^2+42x+45$ **77.** $2x^3-7x^2-24x+45$

78. $3x^5+9x^4+11x^3+21x^2+28x+12$ **79.** px^4+qx^3
$+p^2x^2+p(q+r)x+qr$ **80.** $\frac{1}{2}x^6+\frac{1}{3}x^5+7\frac{5}{12}x^4+4\frac{1}{2}x^3+16\frac{1}{2}x^2$
$+5x+10.$

EXERCISE 39. [Pages 125—128]

1. $x-2$ **2.** $x-5$ **3.** $3x+4$ **4.** $5x-7$
5. $2a-3b$ **6.** x^2-xy+y^2 **7.** $2x-3a$ **8.** $x^2-ax+a^2.$
9. $a^2+2ab-b^2$ **10.** $x+3$ **11.** $2x-1$ **12.** $2ay-b$
13. $am+3n$ **14.** $2x^2+3xy-4y^2$ **15.** $3y^3-x^2y+2x^3$
16. $4m^2-6mn+8n^2$ **17.** $a^3-3a^2y-y^3$ **18.** $27(z+a)$
19. $z-x$ **20.** $x^4+2ax^3+3a^2x^2+2a^3x+a^4$ **21.** x^4-2x^3y
$+3x^2y^2-2xy^3+y^4$ **22.** $x^2+(a+b)x+ab$ **23.** $x-c$
24. $a+b+c$ **25.** $ab+ac+bc$ **26.** $ab+ac-bc$ **27.** x^2-
$(a-b)x-ab$ **28.** $a^2+b^2+c^2-ab-ac-bc$ **29.** x^2+y^2+1
$-xy+x+y$ **30.** $x^2+4y^2+9z^2+2xy+3xz-6yz$ **31.** x^2+
$y^2+z^2+xy-xz+yz$ **32.** $2x-3y-z$ **33.** $ab-ac-bc+c^2$
34. $x+c$ **35.** $x+a$ **36.** $a^2+ab-bc-c^2$ **37.** $ab-ac+bc-b^2$
38. $y^2x+2y^2z+yx^2-2yz^2-x^2z-xz^2$ **39.** x^2-ax+a^2
40. $c+a-b$ **41.** $2(a+b)x$ **42.** $x+y+z+xyz$

43. $16x^4-8x^2(2y^2+a^2)+(4y^2-a^2)^2$ **48.** a^3b **49.** $ab^{-1}c^{\frac{1}{2}}$

50. $-3x^{\frac{1}{3}}y^{\frac{2}{5}}z^{-\frac{1}{3}}$ **51.** $3x^{\frac{2}{3}}-4y^{\frac{1}{3}}$ **52.** $a^{\frac{2}{3}}-a^{\frac{1}{3}}b^{\frac{1}{3}}+b^{\frac{2}{3}}$

53. $a^{\frac{3}{2}}-a^{\frac{3}{4}}b^{\frac{3}{4}}+b^{\frac{3}{2}}$ **54.** $2x^{\frac{4}{3}}-5x^{\frac{2}{3}}y^{\frac{2}{3}}-3y^{\frac{4}{3}}$

55. $a^{\frac{3}{4}}+a^{\frac{1}{2}}b^{\frac{1}{2}}+a^{\frac{1}{4}}b+b^{\frac{3}{2}}$ **56.** $2a^{-5}+3a^{-\frac{5}{2}}b^{-\frac{3}{2}}+5b^{-3}$

57. $3x^{-\frac{5}{4}}-5x^{-\frac{5}{8}}y^{-\frac{3}{8}}+7y^{-\frac{3}{4}}$ **58.** $a^{\frac{5}{2}}+a^2b^{\frac{1}{3}}+a^{\frac{3}{2}}b^{\frac{2}{3}}+ab+a^{\frac{1}{2}}b^{\frac{4}{3}}+b^{\frac{5}{3}}$

59. $x^{\frac{2}{3}}+y^{\frac{2}{3}}+z^{\frac{2}{3}}-x^{\frac{1}{3}}y^{\frac{1}{3}}-y^{\frac{1}{3}}z^{\frac{1}{3}}-z^{\frac{1}{3}}x^{\frac{1}{3}}$

EXERCISE 40. [Pages 129, 130]

1. $m^2-3mn+2n^2$ **2.** $a^2-3ab+b^2$ **3.** $2x^2-3xy-2y^2$ **4.** $a^2-4ax-2x^2$ **5.** $3+2x-2x^2+x^3$ **6.** x^2-2x+3 **7.** $2a^2+3ab-4b^2$ **8.** $a^2-2ax+4x^2$ **9.** $a^2-2ab+2b^2$ **10.** $2x^2-3x-8$ **11.** $x^3+3x^2+9x+27$ **12.** $a^4+2a^3+4a^2+8a+16$ **13.** $3-x^2+2x^3$ **14.** $3x^2-4x+5$ **15.** $32+16x+8x^2+4x^3+2x^4+x^5$ **16.** $x^4+2x^3+3x^2+2x+1$ **17.** $2a^2-3ab+4b^2$ **18.** $a^2+3ab-5b^2$ **19.** $x^3+2x^2a+2xa^2+a^3$ **20.** $a^3-3a^2b-b^3$ **21.** $x^4+2yx^3+3y^2x^2+2y^3x+y^4$ **22.** $x+6+\frac{5}{x+5}$. **23.** $x^2+\frac{1}{3}xy+\frac{1}{9}y^2+\frac{\frac{2}{27}y^3}{x-\frac{1}{3}y}$. **24.** ,
25. $\frac{1}{3}+\frac{7}{9}x+\frac{13}{27}x^2+\frac{1}{81}x^3$ is the quotient and $\frac{4}{81}x^4$ is the remainder

EXERCISE 41. [Pages 131, 132]

13. x^3+x^2+x+1 **14.** $x^3-x^2y+xy^2-y^3$ **15.** $x^4+x^3+x^2+x+1$ **16.** $x^4-x^3y+x^2y^2-xy^3+y^4$ **17.** $x^5+x^4+x^3+x^2+x+1$ **18.** $x^5-x^4y+x^3y^2-x^2y^3+xy^4-y^5$ **19.** $x^6+x^5+x^4+x^3+x^2+x+1$ **20.** $x^6-x^5y+x^4y^2-x^3y^3+x^2y^4-xy^5+y^6$

EXERCISE 42. [Pages 135—137]

1. $25x^2+90xy+81y^2$ **2.** $256a^2-416ab+169b^2$ **3.** $x^2+200x+10000$ **4.** $y^2+1000y+250000$ **5.** $a^2+1998a+998001$ **6.** $y^2+20002y+100020001$ **7.** 976144 **8.** 1024144 **9.** 10100.25 **10.** 9920.16 **11.** $8x^3+60x^2+150x+125$ **12.** 1157625 **13.** 985074.875 **14.** 513152864.216 **15.** (i) 50000032, (ii) 2000288 **16.** (i) $(3x+3y)^2-(x-y)^2$, (ii) $(5x+8y)^2-(x+2y)^2$, (iii) $(x+100)^2-2^2$, (iv) $(500)^2-5^2$ (v) $(2x+100)^2-(4)^2$ **17.** a^4-x^4 **18.** $16a^4-81$ **19.** $a^8+a^4b^4+b^8$ **20** 99999984 **21.** 99999744 **22.** $8a^3+12a^2x+6ax^2+x^3$ **23.** $a^6-12a^4+48a^2-64$ **24.** x^3+64 **25.** $8y^3-27$ **26.** x^6-64 **27.** $4x^2+240x+1575$ **28.** $36x^2+108x-1075$ **29.** $36x^2-408x+1075$ **30.** $100a^2$ **31.** x^2+y^2+2xy **32.** $8000a^3$ **33.** $125a^3$ **34.** $1331a^3$

35. $5x^3$ **36.** $(x+2)(x+3)$ **37.** $5(y+8)(y+5)$
38. $(a^2+2ab+2b^2)(a^2-2ab+2b^2)$ **39.** $(x+y+3)(x+y+12)$
40. $(9a+8b+8)(a+8b-4)$ **41.** $(2x+5y)(4x^2-10xy+25y^2)$
42 $(8a+13x-4)\{(8a+13x)^2+4(8a+13x)+16\}$
43. $(15a+3b+2)(15a+3b-2)$ **44.** $5x(x+2y)(x-3y)$
45. 225 **46.** 512 **47.** 10000 **48.** 8099 999996
49. 92355 **50.** 1 **51.** $(2+5x+3x^2)(2+5x-x^2)$
52. $a^2b^2(x^2+1)^2-(a^2+b^2)^2x^2$
53. $(11x^2+28x+10)^2-(x^2+x+5)^2$
54. $(49x^2+98ax+39a^2)^2+(5a^2)^2$

EXERCISE 43. [Pages 145, 146]

1. (i) 121, (ii) 49, (iii) 4 **3.** 144 sq ft **4.** 15 sq ft
5. 55 sq yds **6.** 84 sq yds **7** 500 sq yds **8.** 50
9. 76 **10.** 171 sq yds

EXERCISE 44. [Page 147]

1. $a(b+c)$ **2.** $a^2b^2(b+a)$ **3.** $x^3y^3(y-2x)$ **4.** $2xyz(x+2y-3z)$
5. $2a^3b(2a^2-3ab-4b^2)$ **6.** $ax^2(y-5axy^2+3x)$
7. $3x^2y^2z^2(x^2y-4y^2z+7z^2x)$ **8.** $14a^5b^5(2a^3-3b^3)$
9. $36x^8y^8(2x^2+3y^2)$ **10.** $13a^5b^5c^5(3b^2c^2-5c^2a^2-7a^2b^2)$

EXERCISE 45. [Pages 147, 148]

1. $(3a+4b)(3a-4b)$ **2.** $a(2a+5x)(2a-5x)$
3 $(6x^2+1)(6x^2-1)$ **4.** $(4x^2+1)(2x+1)(2x-1)$
5. $x(4x^2+3)(4x^2-3)$ **6.** $x(4x^2+9)(2x+3)(2x-3)$
7. $(1+4a^2)(1+2a)(1-2a)$ **8.** $x^2(1+9x^2)(1+3x)(1-3x)$
9. $(6+x^2a)(6-x^2a)$ **10.** $(8a^2+7x^3)(8a^2-7x^3)$
11. $(11+m^8)(11-m^8)$ **12** $(7x^3a^5+9)(7x^3a^5-9)$
13. $(ab+5cd)(ab-5cd)$ **14.** $(9x^6+8a^5)(9x^6-8a^5)$
15. $p^2(q^2+10)(q^2-10)$ **16.** $x^3(12x^2+5a^2)(12x^2-5a^2)$
17. $3a^5(8a^2+9x^2)(8a^2-9x^2)$ **18.** $2ax(7ax^2+8)(7ax^2-8)$
19. $4x^5a^3(9x^6a^3+11)(9x^6a^3-11)$
20. $5m^{15}n^7(7m^4n^8+11)(7m^4n^8-11)$ **21.** $(a+3b+5c)$
$(a+3b-5c)$ **22.** $(a+3b-5c)(a-3b+5c)$ **23.** $4xy$
24. $(5a+3x)(a+x)$ **25.** $(2a-2b+3c-3d)(2a-2b-3c+3d)$

26. $(7x+5y-3z)(7x-5y+3z)$ **27.** $12(5x-1)(x+2)$ **28.** $4a(b-c)$ **29.** $(3a+b-c)(a-7b+9c)$ **30.** $(14a+21x-23y)(2a+27x-41y)$ **31.** $-9(x+a)(x-a)(x^2+a^2)$ **32.** $28a(5a-3)$

EXERCISE 46. [Page 149]

1. $(x^2+x+1)(x^2-x+1)$ **2.** $(x^2+x+1)(x^2-x+1)(x^4-x^2+1)$
3. $(a^2+ax+x^2)(a^2-ax+x^2)$ **4.** $(a^2+ax+x^2)(a^2-ax+x^2)(a^4-a^2x^2+x^4)$ **5.** $(x^2+4x+8)(x^2-4x+8)$
6. $(2x^2+6x+9)(2x^2-6x+9)$ **7.** $9(x^2+2x+2)(x^2-2x+2)$
8. $(a^2+2a+3)(a^2-2a+3)$ **9.** $(x^2+x-3)(x^2-x-3)$
10. $(2x^2+2x+3)(2x^2-2x+3)$ **11.** $(2x^2+2x-3)(2x^2-2x-3)$
12. $(2x^2+3x+3)(2x^2-3x+3)$ **13.** $(2a^2+5a-3)(2a^2-5a-3)$
14. $(2a^2+10a+25)(2a^2-10a+25)$ **15.** $(3x^2+x+4)(3x^2-x+4)$
16. $(3a^2+a-4)(3a^2-a-4)$ **17.** $(3x^2+3x-4)(3x^2-3x-4)$
18. $(3a^2+5a+4)(3a^2-5a+4)$ **19.** $(4x^2-6xa+5a^2)(4x^2+6xa+5a^2)$ **20.** $(3a^2+7ax+5x^2)(3a^2-7ax+5x^2)$
21. $(x^2+4x+12)(x^2-4x+12)$ **22.** $(a^2+5ab-5b^2)(a^2-5ab-5b^2)$ **23.** $(6a^2+2ab-b^2)(6a^2-2ab-b^2)$
24. $(7m^2+2mn-4n^2)(7m^2-2mn-4n^2)$ **25.** $(8a^2+12ax+9x^2)(8a^2-12ax+9x^2)$ **26.** $(2x^2+14xa+49a^2)(2x^2-14xa+49a^2)$
27. $(x+y-z)(x-y+z)$ **28.** $(2a+b-3c)(2a-b+3c)$
29. $(3x+2y-3z)(3x-2y+3z)$ **30.** $(a+2b-5c)(a-2b+5c)$
31. $(4y+3x-5z)(4y-3x+5z)$ **32.** $(a-2b+3c-2d)(a-2b-3c+2d)$ **33.** $(x-2y+z)(x-z)$ **34.** $(2x+3a+5b+1)(2x+3a-5b-1)$ **35.** $(3x+2y-7z-5)(3x-2y+7z-5)$
36. $(4a+3b-4c-3)(4a-3b+4c-3)$ **37.** $(x-7y+5z-2)(x-7y-5z+2)$ **38.** $(4x+5a+3y-7b)(4x+5a-3y-7b)$
39. $(7x-4y+8z-1)(7x-4y-8z+1)$
40. $(a+b-c-d)(a-b+c-d)$

EXERCISE 47. [Page 151]

1. $(a-2b)(a^2+2ab+4b^2)$ **2.** $a(a-3x)(a^2+3ax+9x^2)$
3. $(2x+1)(4x^2-2x+1)(64x^6-8x^3+1)$
4. $(a-2b)(a^2+2ab+4b^2)(a^6+8a^3b^3+64b^6)$
5. $(3a^2+5x^2)(9a^4-15a^2x^2+25x^4)$

6. $(m+n)(m-n)(m^2-mn+n^2)(m^2+mn+n^2)$ 7. $(7x+8y)(49x^2-56xy+64y^2)$ 8. $(2x^2-1)(2x^2+1)(4x^4+2x^2+1)(4x^4-2x^2+1)$ 9. $(a-2x^2)(a+2x^2)(a^2+2ax^2+4x^4)(a^2-2ax^2+4x^4)$ 10. $(5x^3-6a^3)(25x^6+30x^3a^3+36a^6)$ 11. $ab(4a^4+7b^4)(16a^8-28a^4b^4+49b^8)$ 12. $x^2y^2(3x^3+2y^3)(3x^3-2y^3)(9x^6-6x^3y^3+4y^6)(9x^6+6x^3y^3+4y^6)$ 13. $(a+b)^2(a^4-2a^3b+6a^2b^2-2ab^3+b^4)$ 14. $2(x+y)(x-y)(4x^4-14x^2y^2+13y^4)$ 15. $2(a-b)(a^2+ab+b^2)(4a^6-2a^3b^3+b^6)$

EXERCISE 48. [Pages 155 156]

1. $(x+1)(x+2)$ 2 $(x+2)(x+3)$ 3. $(a+1)(a+3)$
4. $(x-4)(x-1)$ 5. $(x+2)(x+5)$ 6. $(x-3)(x-4)$
7. $(x+5)(x+3)$ 8. $(x-5)(x+3)$ 9. $(x-4)(x-9)$
10. $(x+4)(x-9)$ 11 $(x-2)(x-12)$ 12. $(x-2)(x-20)$
13 $(x+10)(x-3)$ 14. $(x+8)(x-6)$ 15. $(x+18)(x-2)$
16. $(x+12)(x-3)$ 17. $(x+14)(x-3)$ 18. $(x+18)(x-4)$
19 $(x-8)(x+5)$ 20. $(x-16)(x+5)$ 21. $(x-32)(x+3)$
22. $(x-14)(x+4)$ 23. $(x-7)(x+6)$ 24. $(x-9)(x+8)$
25. $(x+10)(x+12)$ 26. $(x+20)(x-4)$ 27. $(x-24)(x+3)$
28. $(x+12)(x-7)$ 29. $(x-12)(x-8)$ 30. $(x+26)(x-3)$
31. $(x-12)(x+6)$ 32. $(x-21)(x-4)$ 33. $(x-22)(x-4)$
34. $(x+15)(x-8)$ 35. $(x-10)(x+8)$ 36. $(x+14)(x-6)$
37. $(a-8)(a+7)$ 38. $(m-15)(m+6)$ 39. $(a+20)(a-3)$
40. $(a-9)(a-6)$ 41. $(p-24)(p+2)$ 42. $(m+9)(m-8)$
43. $(m+30)(m-3)$ 44. $(a-24)(a-5)$ 45. $(x+13)(x-6)$
46. $(a-51)(a+2)$ 47. $(a-15)(a-4)$ 48. $(x+16)(x-4)$
49. $(a-30)(a+4)$ 50. $(x+15)(x-7)$ 51. $(x-7y)(x+6y)$
52. $(a-8b)(a-4b)$ 53. $(m+6n)(m-5n)$ 54. $(a+4b)(a-3b)$
55. $(a-5b)(a+3b)$ 56. $(x-8y)(x+y)$ 57. $(x+8y)(x-5y)$
58. $(p-6q)(p-8q)$ 59. $(p+10q)(p-8q)$ 60. $(x+24y)(x-4y)$
61. $(a+1)(a-1)(a^2+5)$ 62. $(x^2+5)(x^2-3)$ 63. $(x+2)(x-2)(x^2+7)$ 64. $(x-1)(x^2+x+1)(x^3+3)$ 65. $(a-2)(a^2+2a+4)(a^3-2)$ 66. $(x-1)(x+3)(x^2+x+1)(x^2-3x+9)$ 67. $(a-1)(a+2)(a^2+a+1)(a^2-2a+4)$ 68. $(x^2+2)(x^2-2)(x+2)(x-2)(x^2+4)$ 69. $(a+2)(a-2)(a^2+4)(a^4+5)$

70. $(x^2+1)(x^2-2)(x^4-x^2+1)(x^4+2x^2+4)$ **71.** $(a+1)^2$ (a^2+2a-2) **72.** $(x+1)(x+2)(x^2+3x+1)$ **73.** $(x-1)^2$ $(x+1)(x-3)$ **74.** $(a+1)(a-4)(a^2-3a+1)$ **75.** $(x+1)(x-5)$ (x^2-4x+1) **76.** $(x+1)(x-2)(x+2)(x-3)$ **77.** $(x-2)$ $(x-3)(x-1)(x-4)$ **78.** $(a-2)(a+9)(a+2)(a+5)$ **79.** $(a-4)$ $(a+10)(a+2)(a+4)$ **80.** $(x+1)(x-9)(x+2)(x-10)$ **81.** $(2x-5)(x+3)$ **82.** $(3a-5)(2a+3)$ **83.** $(4m+3)(2m-3)$ **84.** $(2x-3y)(3x+8y)$ **85.** $(5a-3b)(2a-7b)$ **86.** $(3m-4n)$ $(4m+5n)$ **87.** $(2x+5y)(6x-y)$ **88.** $(4a+5b)(5a-6b)$ **89.** $(3x-5y)(6x-7y)$ **90.** $(4x-3y)(3x+8y)$

EXERCISE 49. [Pages 159, 160]

1. $(x+3)(x+1)$ **2.** $(x+5)(x+1)$ **3.** $(x+5)(x+3)$ **4.** $(x-7)(x-3)$ **5.** $(x-8)(x+6)$ **6.** $(x-9)(x+5)$ **7.** $(x-8)(x-4)$ **8.** $(x-11)(x+5)$ **9.** $(a+2b-c)(a+c)$ **10.** $(x+y)(x-y+2)$ **11.** $(x+y+1)(x-y+5)$ **12.** $(a+5b-c)$ $(a-b+c)$ **13.** $(x-y-z)(x-5y+z)$ **14.** $(x-2y-2z)$ $(x-8y+2z)$ **15.** $(a+b-3c)(a-13b+3c)$ **16.** $(x+12y-3z)$ $(x+3z)$ **17.** $(x+y-5z)(x-15y+5z)$ **18.** $(2x+1)(x-3)$ **19.** $(3x+1)(x-2)$ **20.** $(3x+2)(x+4)$ **21.** $(4x-1)(x+2)$ **22.** $(2x-1)(3x+2)$ **23.** $(2x+1)(3x-4)$ **24.** $(3x-1)(2x+3)$ **25.** $(2x+3)(4x-5)$ **26.** $(2x-5)(2x+7)$ **27.** $(2x-3)(3x+4)$ **28.** $(3x+2)(x-6)$ **29.** $(2x+5)(x-7)$ **30.** $(2x-7)(x+6)$ **31.** $(3x-5)(x+6)$ **32.** $(3x-2)(4x+3)$ **33.** $(a+5b)(2a-3b)$ **34.** $(2x-3y)(3x-2y)$ **35.** $(3m+2n)(2m-5n)$ **36.** $(3p-4q)$ $(p+3q)$ **37.** $(2a-5b)(4a+3b)$ **38.** $(5m-2n)(2m+3n)$ **39.** $(4x-y)(3x+4y)$ **40.** $(3a-4b)(5a+3b)$ **41.** $(2a-b)(a-2b)$ **42.** $(a-3b)(3a+b)$ **43.** $(x+3y)(3x-y)$ **44.** $(a+4)(4a-1)$ **45.** $(a-4b)(4a-b)$ **46.** $(x-5)(5x+1)$ **47.** $(x-5y)(5x-y)$ **48.** $(x+6)(6x+1)$ **49.** $(a+6b)(6a-b)$ **50.** $(a-6b)(6a+b)$ **51.** $(a-7b)(7a-b)$ **52.** $(a+7b)(7a-b)$ **53.** $(a-7b)(7a+b)$ **54.** $(8x-y)(x+8y)$ **55.** $(9x-y)(x-9y)$ **56** $(10x-y)(x+10y)$ **57.** $(2a+2b-1)(a+b+2)$ **58.** $(x-y)^2(2x^2+2y^2+xy)$ **59.** $(a+b)^2(2a^2+2b^2+ab)$ **60.** $(x-4y)(4x-y)(x^2+y^2)$

61. $(x+2)(x-2)(2x^2+3)$ **62.** $(2a+3b)(2a-3b)(2a^2+$,
63. $(3a+4b)(3a-4b)(a^2+2b^2)$. **64.** $(x-2)(2x-1)(x^2+2x+4)$
$(4x^2+2x+1)$ **65.** $(2a^2+b^2)(2a^2-b^2)(a^2+2b^2)(a^2-2b^2)$

Miscellaneous Exercises. III.

[Pages 167—172]

I

1. (i) $y^3(x-2z)-y^2xz+y(xz^2-x^3-2z^3)+(x^3z-xz^3)$,
(ii) $(xy^3-x^3y)+z(x^3-xy^2-2y^3)+z^2xy-z^3(x+2y)$
2. 94 **4.** $x^4+x^3y+x^2y^2+xy^3+y^4$ **5.** $8ab$, 128
6. $2(x^2+y^2+z^2-yz-zx-xy)$ **7.** $(a+c)^2-(b-d)^2$
8. $(2x+3y)(2x+3y-4)$

II

1. $\frac{1}{2}\{9ax^3+3ax^2y+9axy^2+21dy^3\}$ **2.** $m(am+b)(m^2+2)$
3. $x-2x^{\frac{1}{2}}+1$ **5.** $x^3-(a+b+c)x^2+(ab+bc+ca)x-abc$
6. $x^4-(p-1)x^3+(q-p+1)x^2-(p-1)x+1$
7. $a^4+a^2b^2+b^4$ **8.** $(a-b)(b-c)$, $(b+2a+3c)(b-2a-3c)$

III

1. px^3+qx^2+rx+s **2.** $-3b^3$ **3.** 392 **4.** 16
5. $x^2-xy-xz+yz$ **6.** $(4a-1)(16a^2+8a+3)$

IV

1. $-l^4n^2+6l^3mn-2l^3n^3-3l^2m^2n^2-4l^2m^3n+6lm^4n-2m^6$
2. $3a^3x^4+6a^2bx^3+3ab^2x^2+4b^3x+12$ **3.** a^3-64b^2
4. (i) $a^3-3abc+(b^3+c^3)$, (ii) $a^2(b-c)-a(b^2-c^2)+(b^2c-bc^2)$,
(iii) $a^4(b-c)-a(b^4-c^4)+(b^4c-bc^4)$ **5** $x^3+(a+b+c)x^2$
$+(ab+bc+ca)x+abc$, -11, -68 **8** $a+2b+3c$

V

1. 121 **2.** $\frac{1}{2}(ax^5+bx^4y-cx^3y^2-dx^2y^3+exy^4-fy^5)$
4. $8a^3+12a^2c+6ac^2+c^3$ **5.** $8x^6+4x^5+12x^4-8x^2+24x-32$
7. $a^{\frac{3}{4}}+a^{\frac{1}{2}}b^{\frac{1}{4}}+a^{\frac{1}{4}}b^{\frac{1}{2}}+b^{\frac{3}{4}}$ **8.** (i) $a^2x(a-x)(6ax+1)$,
(ii) $(x+yz)(y+zx)$

VI.

1. 87659405 **2.** -125 **4.** x^2+1 **5.** $(x^2-7x+9)^2+(5)^2$
6. $(a+b+c+d)(a-b-c+d)(a+b-c-d)(a-b+c-d)$
7. (i) $(a-b)(a-b+2)$, (ii) $(2a-b)(3a+b+3)$; (iii) $(5x+2y)(3x-2y+2)$ **8.** $(2x-y)a^2+(x+y)ax-x^3$

VII

1. 7 **3.** $x^{\frac{1}{2}}+y^{\frac{1}{2}}+z^{\frac{1}{2}}-3x^{\frac{1}{2}}y^{\frac{1}{2}}z^{\frac{1}{2}}$ **4.** $x+a$
6. $2x^2y^2+2y^2z^2+2z^2x^2-x^4-y^4-z^4$ **7.** (i) $(2x-3)(3x+5)$, (ii) $(5x-5y-3)(7x-7y-4)$, (iii) $(x-3y^2)(11x-21y^2)$

VIII

1. $1+(a+b)x+\dfrac{(a+b)(a+b-1)x^2}{2}$. **2.** 55 **4.** $2(a+b)x$
5. a^2-2, a^3-3a, a^4-4a^2+2
8. $(x^2-3xy-y^2)(x^3+3xy-y^2)$

IX

1. $a^4+a^2x^2+x^4$ **4.** $x^3+6x+\dfrac{12}{x}+\dfrac{8}{x^3}$.
6. $a^2(b-c)-a(b^2-c^2)+bc(b-c)$ **8.** 3

X

1. $2(a+m)(c+n)+2bd$ **2.** 16 **5.** $a^{\frac{3}{2}}+b+c^{\frac{1}{4}}-3a^{\frac{1}{2}}b^{\frac{1}{3}}c^{\frac{1}{4}}$
6. $(3x-7)(5x-2)$ **7.** 17 **8.** £125 each

EXERCISE 51. [Page 175]

1. a^2b^2 **2.** $4a^2$ **3.** $3xy^2$ **4.** $5a^2y^3$ **5.** $9m^2n^3$ **6.** $4ax$
7. $12mp$ **8.** $15x^2y^2z^2$ **9.** $18a^2c^2$ **10.** $24c^3$ **11.** $12z^2$
12. $15m^3n^3p^3q^3$ **13.** $18a^2b^2c^2d^2$ **14.** 6 **15.** $8x^2y^2$

EXERCISE 52. [Pages 176, 177]

1. $a(a+b)$ **2.** $x^3y^3(x+y)$ **3.** $3(x+3)$ **4.** $4a^2(a^2+bc)$
5. $m^3n^3(m-n)^2$ **6.** $ax(2a+3x)$ **7.** $2a^2b^2(3a+4b)$ **8.** $3x^2y^2(x-2y)$ **9.** $2ab(a+2b)$ **10.** $16x^3a^3(x^2-a^2)$ **11.** $8(x^2+ax+a^2)$
12. $8xa^2(x^2+a^2)$ **13.** $6(a+3b)$ **14.** $4x(x-5)$

15. $xy(x+6y)$ **16.** $a^2x^2(a+2x)$ **17.** $2x+3$ **18.** $a-2b$
19. $x-2$ **20.** $18(x+2a)$ **21.** $a-b$ **22.** $x+2$
23. $4ab(3a+b)$ **24.** x^2+5x+6

EXERCISE 53. [Page 180]

1 a^2b^2 **2** a^3b^2c **3.** $30x^2y^4$ **4.** $28m^4n^3p$ **5.** $24x^3y^3z^2$
6. $140a^2b^2c^2$ **7.** $120a^3b^3c^3$ **8.** $180x^4y^3z^2a^2$
9. $a^2b^2(a^2-b^2)$ **10.** $24(x^2-y^2)^2$ **11** $(x-1)(x-2)(x-3)$
12. $a^2(a-x)(a+3x)(a-2x)$ **13.** $a^2(a-2)(a+2)(a+4)$
14. $12a^3x^2(x^2-a^2)(x^2-ax+a^2)$ **15.** $48(x-2)(x+5)(x+6)$
16. $(x-3)(x+5)(x+4)(x+7)$ **17.** $3a^2(4a^2-9b^2)(a^2-b^2)$
18. $(8a^3+27b^3)(8a^3-27b^3)$ **19.** $12x^2(4x^2-25y^2)(2x-y)$
20. $(2x-3a)^2(9x^2-a^2)$ **21.** $2x(4x^4+81)$
22 $6(3a-x)^2(a^2-4x^2)$ **23.** $(2x-1)^2(4x^2-1)(x+3)$
24. $(x-2y)(x-4y)(x-3y)(x+5y)$ **25.** $(x+2)(2x-1)(3x+1)$
26. $(1-4x^2)(1+2x+4x^2)(1+2x-4x^2)$
27. $(x^2-3)^2(9x^2-1)(9x^4-1)$

EXERCISE 54. [Page 183]

1. $\frac{1}{2b}$ **2** $\frac{3x}{4y}$. **3** $\frac{2a}{5x}$ **4.** $\frac{3xz}{5y^2}$.
5. $\frac{2d}{3ab}$ **6.** $\frac{2az}{5xy}$. **7.** $\frac{2d^5}{3a}$ **8.** $\frac{3npq}{5m}$.
9 $\frac{x-a}{x}$. **10.** $-\frac{1}{x+3}$. **11.** $\frac{2x-3a}{2x}$ **12** $-\frac{a}{a+4b}$
13 $\frac{3a}{x+4a}$ **14.** $\frac{2x^2}{x^2-2a^2}$. **15** $\frac{4x}{x+3}$. **16.** $\frac{x-2}{x-3}$
17. $\frac{x-3}{x+4}$ **18.** $\frac{a-4b}{a-5b}$ **19** $-\frac{a^2}{a+b}$ **20.** $\frac{1-4x}{1-5x}$
21. $-\frac{x-y}{x+7y}$ **22.** $\frac{1-2a^2}{1+3a^2}$ **23** $\frac{x^2-13}{x^2-4}$. **24.** $\frac{3ax}{a-3x}$
25. $\frac{2x+3}{3x+4}$ **26** $\frac{x-a}{x+a}$ **27.** $\frac{x+5a}{x+7a}$ **28** $\frac{2x-5}{3x-2}$.
29. $\frac{2x-5a}{3x-7a}$ **30.** $\frac{2-3ax}{1-5ax}$. **31.** $\frac{x-a}{x^2+a}$. **32.** $\frac{3a+5b}{3c-1}$
33. $\frac{2x+3a}{3x+2a}$. **34.** $\frac{2a-b}{a^2-1}$. **35.** $\frac{a-b-c}{a+b-c}$.

EXERCISE 55. [Pages 185. 186]

1. $\frac{2adf}{4bdf}, \frac{3bcf}{4bdf}, \frac{4bde}{4bdf}$. 2. $\frac{6ax^2}{12abc}, \frac{4by^2}{12abc}, \frac{3cz^2}{12abc}$.

3. $\frac{15x^2ab}{60x^3y^2}, \frac{10xybc}{60x^3y^2}, \frac{6y^2ca}{60x^3y^2}$. 4. $\frac{a^2(a+b)}{a(a^2-b^2)}, \frac{ab(a-b)}{a(a^2-b^2)}, \frac{c(a-b)}{a(a^2-b^2)}$.

5. $\frac{x^2(a-2b)}{a(a^2-4b^2)}, \frac{ay^2(a+2b)}{a(a^2-4b^2)}$. 6. $\frac{2a^2}{a(a-b)}, \frac{c-a}{a(a-b)}$.

7. $\frac{2a(a+b)}{a^2-b^2}, \frac{-3b(a+b)}{a^2-b^2}, \frac{4c(a-b)}{a^2-b^2}$

8. $\frac{2b^2c^2x(a-x)}{a^2b^2c^2(a^2-x^2)}, \frac{3c^2a^2y(a+x)}{a^2b^2c^2(a^2-x^2)}, \frac{4a^2b^2z}{a^2b^2c^2(a^2-x^2)}$.

9. $\frac{a^2x(2x+3y)}{xy(4x^2-9y^2)}, \frac{b^2y(2x-3y)}{xy(4x^2-9y^2)}, \frac{c^2}{xy(4x^2-9y^2)}$.

10. $\frac{a^2(x^2-x+1)}{x^4+x^2+1}, \frac{b^2(x^2+x+1)}{x^4+x^2+1}$. 11. $\frac{3(x+3)}{x^3+2x^2-5x-6}, \frac{4(x+1)}{x^3+2x^2-5x-6}$

12. $\frac{a^2-4b^2}{a^4+8ab^3}, \frac{abc}{a^4+8ab^3}$.

13. $\frac{a(a^2+3ab+9b^2)}{a^3-27b^3}, \frac{b(a-3b)}{a^3-27b^3}, \frac{c}{a^3-27b^3}$

14. $\frac{a^2(a-b+c)}{ab(a^2+b^2-c^2-2ab)}, \frac{b^2(a-b-c)}{ab(a^2+b^2-c^2-2ab)}, \frac{abc}{ab(a^2+b^2-c^2-2ab)}$

15. $\frac{(c-a)^2}{(a-b)(b-c)(c-a)}, \frac{(a-b)^2}{(a-b)(b-c)(c-a)}, \frac{(b-c)^2}{(a-b)(b-c)(c-a)}$.

EXERCISE 56. [Pages 188—190]

1. $\frac{a^2+b^2}{ab}$. 2. 0 3. 1 4. $\frac{4ab}{a^2-b^2}$.

5. $\frac{a+b}{2(a-b)}$. 6. $\frac{12xy}{4x^2-9y^2}$. 7. $\frac{a^2-2ab-b^2}{(a+b)^2(a-b)}$.

8. $\frac{2a^3}{a^2-b^2}$. 9. $\frac{1}{(a-b)(b-c)}$. 10. $\frac{2}{x^2-4x+3}$.

11. $\frac{2}{x^2+10x+16}$. 12. $\frac{6xy}{8x^3+27y^3}$. 13. $\frac{2ab}{a^2-b^2}$.

14. 0 15. $\frac{8x^2y^2}{x^4-y^4}$. 16. $\frac{-64ax^3}{a^4-16x^4}$

17. $\frac{x^2}{6(x^2-9)}$. **18.** $\frac{2b}{1-16a^2b^2}$. **19.** $\frac{4x^4}{x^4-16a^4}$.

20. $\frac{8a^7b}{a^8-b^8}$. **21.** $\frac{108x^4}{81x^4-y^4}$. **22.** $\frac{9ax(x+a)}{x^4-81a^4}$.

23. $\frac{4ab}{(a-b)^2}$. **24.** $\frac{6x^2-12}{x^4-5x^2+4}$. **25.** $\frac{6a^2x}{4x^4-5a^2x^2+a^4}$.

26. $\frac{48a^3}{x^4-10a^2x^2+9a^4}$. **27.** $\frac{2x}{x^4-1}$ **28.** $\frac{x-c}{(x-a)(x-b)}$.

29 $\frac{4}{x^2-6x+5}$. **30.** $\frac{4}{x^2+14ax+13a^2}$. **31.** $\frac{2}{x+3}$.

32. 0 **33.** $\frac{4x^3}{1+x^4+x^8}$ **34.** $\frac{12x^4}{x^6-64}$

35. $\frac{66ax^5}{16x^8-6561a^8}$.

EXERCISE 57. [Pages 191 192]

1. $\frac{1}{3}$ **2.** $\frac{a^2}{9}$. **3.** xyz **4.** $\frac{x^2y^2z^2}{9a^2b^2c^2}$.

5. $\frac{5n^2x^2}{8my}$. **6** $\frac{x+2}{x}$. **7.** 3 **8.** $\frac{a^2-b^2}{a}$.

9. $\frac{a^2-4x^2}{a^2}$. **10.** $\frac{x^2-1}{x^2-x-6}$. **11.** 1 **12.** 1

13. $\frac{a^2+b^2}{a}$ **14.** $\frac{x}{2}$. **15.** $\frac{x+2}{x+3}$. **16.** $\frac{a^2(a-b)}{x}$,

17. $\frac{x^4}{a^4}+\frac{x^2}{a^2}+1$ **18.** $\frac{8ab}{9x^2}+2+\frac{9x^2}{8ab}$. **19.** $2\left(\frac{bc}{ad}+\frac{ad}{bc}\right)$.

20. 1 **21.** $\frac{a+b-c}{a+b+c}$. **22.** 1

EXERCISE 58. [Pages 195 196]

1. $\frac{5ax}{6by}$. **2.** $\frac{(a+b)^2}{b}$. **3.** $\frac{x-7}{x-5}$. **4.** $a-b$

5. $\frac{m-n}{m+2n}$ **6.** $(m-n)^2$ **7.** 1 **8.** 1 **9.** $\frac{x^2+y^2}{2xy}$.

10. $\frac{x^2-8x+12}{x^2-10x+21}$. **11.** $\frac{1}{p^2+q^2}$. **12.** a^2-b^2 **13.** xy

14. ab **15.** $2x$ **16.** 1 **17.** $\frac{xy}{x^2+y^2}$.

18. $-\frac{a^4+a^2b^2+b^4}{ab(a-b)^2}$. **19.** $\frac{a}{a-b}$. **20.** a^2-b^2 **21.** $a-b$

EXERCISE 59. [Pages 199—201]

1. 2 **2.** 2 **3.** -5 **4.** 1 **5.** 2 **6.** $\frac{1}{2}$ **7.** 3
8. -5 **9.** 6 **10.** $a+b$ **11.** $2a$ **12.** $\frac{1}{2}(a+b)$. **13.** $a+b$
14. $m-n$ **15.** $a+b$ **16.** $\frac{a+b}{4}$. **17.** $\frac{2ab}{a+b}$. **18.** $\frac{12ab}{a+3b}$
19. $c+d$ **20.** $\frac{1}{3}(a+b+c)$ **21.** $-\frac{1}{3}(a+b+c)$
22. ab **23.** $\frac{1}{ab}$. **24.** 13 **25.** 16 **26.** 20
27. -3 **28.** 8 **29.** 10 **30.** 9 **31.** 9
32. 5 **33.** 8 **34.** 5 **35.** 7 **36.** $\frac{8a}{25}$.
37. 24 **38.** 18 **39.** $\frac{6a}{7}$ **40.** 56 **41.** $4\frac{1}{2}$
42. 6 **43.** $10\frac{3}{8}$ **44.** $\frac{ac+b^2}{b^2+c^2}$. **45.** $-2\frac{39}{73}$ **46.** 8 **47.** 11
48. 2 **49.** $25a+24b$ **50.** $\frac{2ab}{a+b}$. **51.** 72 **52.** $7\frac{1}{2}$

EXERCISE 60. [Page 202]

1. 27 **2.** 5 **3.** 20 **4.** 2 **5.** 10
6. 5 **7.** 5 **8.** 5 **9.** 7 **10.** 5

EXERCISE 61. [Pages 203, 204]

1. $\frac{15}{16}$ **2.** $\frac{3}{2}$ **3.** $2\frac{4}{7}$. **4.** 4·05 **5.** 3
6. 3 **7.** $10\frac{7}{8}$ **8.** $a^2+b^2+c^2$ **9.** $\frac{1}{3}(ab+bc+ca)$
10. 0 **11.** $a^3+b^3+c^3-3abc$ **12.** 0

EXERCISE 62. [Pages 208, 209]

1. 90 by 180, 100 by 230 **2.** 15 ft, 12 ft
3. £33 **4.** 50, 30 **5.** 20 men, 16 women
6. A, 84 miles and B, 70 miles in 56 hours **7.** 28 days
8. £2 15s **9.** 24 ft **10.** Worked for 22 days.

11. 4 days **12.** £52, 52*s* **13.** *A*, £162, *B*, £118. *C* £104 **14.** 34 sheep, £70 **15.** $98\frac{2}{5}$ miles from London. $10\frac{2}{3}$ hours **16.** 44 **17.** 32 **18.** 72 **19.** 23. **20.** 5, 8 2 24 **21.** 19. 5 4, 32 **22.** 22 31, 9, 54.

EXERCISE 63. [Page 212]

1. $\left.\begin{matrix}x=2\\y=3\end{matrix}\right\}$ **2.** $\left.\begin{matrix}x=5\\y=2\end{matrix}\right\}$ **3.** $\left.\begin{matrix}x=7\\y=6\end{matrix}\right\}$ **4.** $\left.\begin{matrix}x=4\\y=7\end{matrix}\right\}$.

5. $x=\dfrac{ac+b^2}{a^2+b}$, $y=\dfrac{ab-c}{a^2+b}$. **6.** $\left.\begin{matrix}x=2\\y=3\end{matrix}\right\}$ **7.** $\left.\begin{matrix}x=40\\y=16\end{matrix}\right\}$.

8. $\left.\begin{matrix}x=8\\y=5\end{matrix}\right\}$ **9.** $\left.\begin{matrix}x=6\\y=4\end{matrix}\right\}$ **10.** $\left.\begin{matrix}x=6\\y=8\end{matrix}\right\}$

EXERCISE 64. [Page 214]

1. $\left.\begin{matrix}x=3\\y=2\end{matrix}\right\}$ **2.** $\left.\begin{matrix}x=2\\y=3\end{matrix}\right\}$ **3.** $\left.\begin{matrix}x=7\\y=2\end{matrix}\right\}$ **4.** $\left.\begin{matrix}x=3\\y=7\end{matrix}\right\}$

5. $\left.\begin{matrix}x=4\\y=4\end{matrix}\right\}$ **6** $\left.\begin{matrix}x=13\\y=\ 3\end{matrix}\right\}$ **7.** $\left.\begin{matrix}x=6\\y=5\end{matrix}\right\}$ **8.** $\left.\begin{matrix}x=5\\y=5\end{matrix}\right\}$.

9. $\left.\begin{matrix}x=2\frac{1}{2}\\y=1\frac{1}{2}\end{matrix}\right\}$ **10.** $\left.\begin{matrix}x=6\\y=2\end{matrix}\right\}$

EXERCISE 65. [Pages 217, 218]

1. $\left.\begin{matrix}x=3\\y=2\end{matrix}\right\}$ **2.** $\left.\begin{matrix}x=4\\y=1\end{matrix}\right\}$ **3.** $\left.\begin{matrix}x=7\\y=4\end{matrix}\right\}$ **4.** $\left.\begin{matrix}x=2\\y=3\end{matrix}\right\}$

5. $\left.\begin{matrix}x=4\\y=2\end{matrix}\right\}$ **6.** $\left.\begin{matrix}x=6\\y=4\end{matrix}\right\}$ **7.** $\left.\begin{matrix}x=2\\y=1\end{matrix}\right\}$ **8.** $\left.\begin{matrix}x=-2\\y=\ \ 3\end{matrix}\right\}$.

9. $\left.\begin{matrix}x=5\\y=2\end{matrix}\right\}$ **10** $\left.\begin{matrix}x=1\\y=3\end{matrix}\right\}$ **11.** $\left.\begin{matrix}x=1\\y=2\end{matrix}\right\}$ **12.** $\left.\begin{matrix}x=\ \ 3\\y=-1\end{matrix}\right\}$.

13. $\left.\begin{matrix}x=1\\y=4\end{matrix}\right\}$ **14.** $\left.\begin{matrix}x=-5\\y=\ \ 2\end{matrix}\right\}$ **15.** $\left.\begin{matrix}x=-2\\y=\ \ 1\end{matrix}\right\}$ **16.** $\left.\begin{matrix}x=\ 5\\y=11\end{matrix}\right\}$

17. $x=\dfrac{bc-c^2}{ba-a^2}$, $y=\dfrac{ac-c^2}{ab-b^2}$. **18** $\left.\begin{matrix}x=7\\y=9\end{matrix}\right\}$

19. $\left.\begin{matrix}x=\frac{1}{4}\\y=\frac{1}{5}\end{matrix}\right\}$ **20.** $\left.\begin{matrix}x=3\\y=2\end{matrix}\right\}$ **21.** $\left.\begin{matrix}x=2\\y=3\end{matrix}\right\}$ **22.** $\left.\begin{matrix}x=7\\y=4\end{matrix}\right\}$.

23. $\left.\begin{matrix}x=10\\y=\ 5\end{matrix}\right\}$ **24.** $\left.\begin{matrix}x=\ 4\\y=10\end{matrix}\right\}$ **25.** $\left.\begin{matrix}x=2\\y=3\end{matrix}\right\}$.

26. $x=\dfrac{a^2-b^2}{am-bn}$, $y=\dfrac{a^2-b^2}{an-bm}$. **27.** $x=\frac{2}{3}$, $y=\frac{3}{5}$

28 $x=\frac{1}{5}$ $y=\frac{1}{2}$ **29.** $x=4$ $y=2$ **30** $x=\frac{1}{15}$, $y=18$.

EXERCISE 66. [Pages 223—225]

1. $\frac{4}{5}$ **2.** 7 9 **3.** 6, 2 **4.** 60, 15 **5.** 24 15
6. $\frac{6}{13}$ **7.** $\frac{2}{3}$ **8.** $\frac{3}{5}$ **9.** Rs 15, Rs 24 **10.** 3, 5
11. 6 miles and 3 miles per hour **12.** 8, 16 **13.** 20 days
14. 480 sq yards **15.** Tea $2s$ $8d$ and coffee $1s$ $6d$ per lb
16. 3 miles, $4\frac{2}{7}$ miles per hour **17.** 22 and 26 **18.** A, Rs 500
B, Rs 400, C Rs 200 **19.** 75 **20.** 65 **21.** 21 40
22. A horse, £24, a cow £12 **23.** $5s$, $3s$ **24.** A 24 days
B 48 days **25.** $\frac{8}{15}$ **26.** 15 miles **27** 72 **28.** $75s$, $35s$
29. 34 sheep £70 **30.** 27

EXERCISE 67. [Page 231]

7. (1) $6x-5y=0$, (2) $5x+7y=35$, (3) $x+y+2=0$,
(4) $21x-5y+124=0$, (5) $5x+9y+55=0$

EXERCISE 68. [Pages 233, 234]

1. 3, −3 **2.** a −a **3.** 14, −14 **4.** $2\frac{1}{3}$, −$2\frac{1}{3}$ **5.** 5 −5
6. 3 −3 **7.** 5, −5 **8.** $2a$ −$2a$ **9.** a, −a **10.** 6, −6
11. 1 −1 **12.** 2 −2 **13.** 6 yds **14.** 9 yds **15.** 5 ft
each

EXERCISE 69. [Page 236]

1. 2, 4 **2.** 5, −4 **3.** 1, −4 **4.** 4, −13 **5.** 3 $-\frac{4}{3}$
6. $\frac{1}{2}$ $-\frac{4}{7}$ **7.** 7 $-\frac{1}{3}$ **8.** 2 $\frac{1}{2}$ **9.** 2, $-\frac{2}{15}$ **10.** a, b
11. 19 21 **12.** 16, −6 **13.** 3, 13 **14.** 40 yrs **15.** Rs. 75

Miscellaneous Exercises. IV.

[Pages 236—241]

I

1. $12a^3$, $720a^6b^4c^5x^2y^3$ **2.** $(x-3)^2$, $(x-3)(4x+1)$, $x-3$
3. $(a-b)(b-c)(b-2a-3c)(2a+b+3c)$ **4.** $(x+y-1)$
$(x^2+y^2-xy+x+y+1)$ **6.** x^4+2 **7.** $x=\dfrac{b}{a^2-ab+b^2}$,
$y=\dfrac{a}{a^2-ab+b^2}$. **8.** $\dfrac{ab}{a+b}$ hours, $\dfrac{abc}{ab-bc-ac}$ hours

II

1. $x-3$ 2. $(x-a)(x+b)(x^2+a)$ 3. (i) $\frac{9}{4}x^2y^2$, (ii) 3
4. $\frac{a^4+b^4}{a^2b^2}$. 5. $\frac{5(x-3)}{3(x-5)}$. 7. 9 8. $x=\frac{b^2+c^2-a^2}{2a}$, $y=\frac{c^2+a^2-b^2}{2b}$.

III

1. $(a-b)(x+a)$ 2. x^6-1 3. $x+3$ 4. $(x+a)(x-b)(x+b)$
5. $\frac{8}{x^4-16}$. 6. $x=\frac{2(b-1)}{2ab-a-b}$, $y=\frac{2(a-1)}{2ab-a-b}$.
7. £2800 and £1200 8. 3, -3

IV

2. $x-y$ 3. $\frac{1}{x^2-3x+2}$. 4. $\frac{1}{m^2-m+1}$. 6. 345
7. $\frac{13}{21}$ 8. 8, -8

V

1. $x^2-(a+b)x+ab$ 2 $280x^3-123x^2-37x+6$. 3. 1
4. $\frac{1}{a+c}$. 8 4, -4.

VI

1. $x-2$ 2. $abc(x-a)(x-b)(x-c)$ 4. 0 6. 2
7. 125 8. 4, -4.

VII

1. x^2+5 2. $(a-b)(b-c)(c-a)$ 4. $\frac{3}{x^2-4x+3}$.
5. $\frac{a^2+b^2}{2ab}$. 7. $x=10, y=15$ 8. 4, -4

EXERCISE 70. [Pages 242 243]

1. $x^3+6x^2+11x+6$ 2. $x^3+14x^2+59x+70$ 3. $x^3-x^2-24x-36$ 4 $x^3-x^2-70x-200$ 5. $x^3-4x^2-29x-24$
6. $x^3+x^2-46x+80$ 7. $x^3-37x+84$ 8. $x^3-6x^2-37x+210$
9. $x^3-23x^2+167x-385$ 10. $x^3-18x^2+99x-162$
11. $x^3-13x^2-8x+240$ 12. $x^3+25x^2+199x+495$

13. $x^3-52x+96$ **14.** $x^3-23x^2+151x-273$ **15.** x^3+13x^2-144 **16.** $x^3-7x^2-138x+1080$ **17.** $x^3-3x^2-73x+315$ **18.** $x^3+35x^2+396x+1140$ **19.** $x^3-148x-672$ **20.** $x^3-31x^2+290x-800$

EXERCISE 71. [Pages 244, 245]

1. $x^2+y^2+z^2+2xy-2xz-2yz$ **2.** $x^2+y^2+z^2-2xy+2xz-2yz$ **3** $x^2+y^2+z^2-2xy-2xz+2yz$ **4.** $x^2+y^2+z^2+2xy-2xz-2yz$ **5.** $x^2+y^2+z^2-2xy-2xz+2yz$ **6.** $a^2+x^2+y^2+z^2-2ax+2ay-2az-2xy+2xz-2yz$ **7.** $a^2+x^2+y^2+z^2-2ax-2ay-2az+2xy+2xz+2yz$ **8.** $m^2+n^2+p^2+q^2+r^2+2mn+2mp+2mq+2mr+2np+2nq+2nr+2pq+2pr+2qr$ **9.** $p^2+q^2+r^2+x^2+y^2-2pq+2pr-2px-2py-2qr+2qx+2qy-2rx-2ry+2xy$ **10.** $a^2+b^2+c^2+x^2+y^2+z^2-2ab+2ac-2ax+2ay+2az-2bc+2bx-2by-2bz-2cx+2cy+2cz-2xy-2xz+2yz$ **11.** $a^2+4x^2+9y^2+16z^2-4ax-6ay-8az+12xy+16xz+24yz$ **12.** $4a^2+b^2+4c^2+d^2-4ab+8ac-4ad-4bc+2bd-4cd$ **13.** 49 **14.** 9 **15.** 0 **16.** 144 **17.** 1635 **18.** 1 **19.** 63 **20.** 0 **21.** 47 **22.** 69

EXERCISE 72. [Page 248]

1. $x^5+5x^4+10x^3+10x^2+5x+1$ **2.** $x^6+6x^5+15x^4+20x^3+15x^2+6x+1$ **3.** $a^8+8a^7b+28a^6b^2+56a^5b^3+70a^4b^4+56a^3b^5+28a^2b^6+8ab^7+b^8$ **4** $a^9+9a^8b+36a^7b^2+84a^6b^3+126a^5b^4+126a^4b^5+84a^3b^6+36a^2b^7+9ab^8+b^9$ **5.** $x^5-5x^4y+10x^3y^2-10x^2y^3+5xy^4-y^5$ **6.** $m^7-7m^6n+21m^5n^2-35m^4n^3+35m^3n^4-21m^2n^5+7mn^6-n^7$ **7.** $x^4+8x^3+24x^2+32x+16$ **8.** $x^5+10x^4+40x^3+80x^2+80x+32$ **9.** $x^8+8x^7+28x^6+56x^5+70x^4+56x^3+28x^2+8x+1$ **10.** $x^4+12x^3+54x^2+108x+81$ **11.** $x^5-5x^4+10x^3-10x^2+5x-1.$ **12.** $64-192z+240z^2-160z^3+60z^4-12z^5+z^6$ **13.** $16x^4-32x^3+24x^2-8x+1$ **14.** $x^9-9x^8y+36x^7y^2-84x^6y^3+126x^5y^4-126x^4y^5+84x^3y^6-36x^2y^7+9xy^8-y^9$ **15.** $243x^5-810x^4+1080x^3-720x^2+240x-32$ **16.** $1-8a+28a^2-56a^3+70a^4-56a^5+28a^6-8a^7+a^8$ **17.** $1-7c+21c^2-35c^3+35c^4-21c^5+7c^6-c^7$

18. $1-18x+135x^2-540x^3+1215x^4-1458x^5+729x^6$ **19.** $1-14x+84x^2-280x^3+560x^4-672x^5+448x^6-128x^7$ **20.** $256x^8-1024x^7a+1792x^6a^2-1792x^5a^3+1120x^4a^4-448x^3a^5+112x^2a^6-16xa^7+a^8$ **21.** $x^{10}-10x^9a+45x^8a^2-120x^7a^3+210x^6a^4-252x^5a^5+210x^4a^6-120x^3a^7+45x^2a^8-10xa^9+a^{10}$
22. $243x^5-810x^4a+1080x^3a^2-720x^2a^3+240xa^4-32a^5$
23. $10x^4+20x^2+2$ **24.** $2x^6+30x^4+30x^2+2$
25. $14x^6a+70x^4a^3+42x^2a^5+2a^7$ **26.** 16 **27.** 32 **28.** 64
29. 128 **30.** 256 **31.** 30 **32.** 3 **33.** 0 **34.** 16 **35.** 0

EXERCISE 73. [Page 250]

1. $x^3+y^3-z^3+3xyz$ **2.** $p^3-8q^3-r^3-6pqr$. **3.** $8x^3-27y^3-z^3-18xyz$ **4.** $a^3-8b^3+27+18ab$ **5.** $27a^3-125b^3-64-180ab$ **6.** $(x-y-1)(x^2+y^2+1+xy+x-y)$ **7.** $(x-y+2)(x^2+y^2+4+xy-2x+2y)$ **8.** $(x-2y-3z)(x^2+4y^2+9z^2+2xy+3xz-6yz)$ **9.** 0 **10.** 0 **11.** 0 **16.** 0 **17.** 392000

EXERCISE 74. [Pages 251, 252]

3. $8(b-c)(c-a)(a-b)$ **4.** $(y-z)(z-x)(x-y)$ **5.** 0 **6.** 0

EXERCISE 75. [Pages 253 254]

1. $2x^2y+3x^2z+12y^2z+4y^2x+9z^2x+18z^2y+12xyz$ **2.** $64x^2y+320x^2z+5y^2z+8y^2x+200z^2x+25yz^2+80xyz$ **3.** $2a^2b+3a^2c+12b^2c+4ab^2+9ac^2+18bc^2+12abc$ **4.** $9x^2y+90x^2z+10y^2z+3xy^2+300z^2x+100z^2y+90xyz$ **5.** $2x^3+2y^3+2z^3+7(x^2y+x^2z+y^2z+y^2x+z^2x+z^2y)+16xyz$ **6.** $2a^2b-3a^2c-12b^2c-4ab^2-9ac^2+18bc^2+12abc$ **7.** $4abc$ **8** $4abc$
9 0 **10.** $27abc$

EXERCISE 76. [Pages 255 256]

4. 0 **8.** $84abc$ **9** $6xyz$ **10.** $3(y+z-x)(2x-2y+z)(x+y-2z)$ **11.** $3(2x+3y+3z)(3x+2y+3z)(3x+3y+2z)$
12. 2567 **13** 16800 **14.** 1280 **15.** 1331

EXERCISE 77. [Page 259]

1. $(x^2+y^2+z^2+yz+zx-xy)(x+y-z)$ 2. $(p-2q-r)(p^2+4q^2+r^2+2pq+pr-2qr)$ 3. $(2x-3y-z)(4x^2+9y^2+z^2-3yz+2zx+6xy)$ 4. $(a+2b+1)(a^2+4b^2+1-2b-a-2ab)$ 5. $(2a+3b-4)(4a^2+9b^2+16+12b+8a-6ab)$ 6. $x^2+y^2+4+2y-2x+xy$ 7. $(x^2-x+2)(x^4+x^3-x^2+2x+4)$ 8. $2(z-y)(3x^2+y^2+z^2+yz-3zx-3xy)$ 9. $(a^2+3a+5)(a^4-3a^3+4a^2-15a+25)$ 10. $x-5y+3$ 11. $a^2+b^2+c^2-ab+ac+bc$ 12. $x^2+y^2+1+xy+x-y$ 13. $x^2+4y^2+9z^2+2xy-3zx+6yz$ 14. $2a-3b-c$ 15. $(2a-b)(7a^2+8ab+4b^2)$

EXERCISE 78. [Pages 263, 264]

1. $-(b-c)(c-a)(a-b)(a^2+b^2+c^2+bc+ca+ab)$ 2. $-(b-c)(c-a)(a-b)(b+c)(c+a)(a+b)$ 3. $-(b-c)(c-a)(a-b)\{a^3+b^3+c^3+a^2(b+c)+b^2(c+a)+c^2(a+b)+abc\}$ 4. $-(b-c)(c-a)(a-b)(a^2+b^2+c^2+bc+ca+ab)$ 5. $-(b-c)(c-a)(a-b)(bc+ca+ab)$ 6. $(y+z)(z+x)(x+y)$ 7. $(y-z)(z-x)(x-y)(yz+zx+xy)$ 8. $5(y-z)(z-x)(x-y)(x^2+y^2+z^2-yz-zx-xy)$ 9 $-(y-z)(z-x)(x-y)$ 10. $-(b-c)(c-a)(a-b)$ 11. $-(b-c)(c-a)(a-b)$ 12. $(a+b+c)(bc+ca+ab)$ 13. $3(2x-y+z)(x-z)(x+y)$ 14. $-(b-c)(c-a)(a-b)(b^2+bc+c^2)(c^2+ca+a^2)(a^2+ab+b^2)$ 15 $-(y-z)(z-x)(x-y)(y+z)(z+x)(x+y)(y^2z^2+z^2x^2+x^2y^2)$ 16. $3(2a+b+c)(a+2b+c)(a+b+2c)$ 17. $(y+z-x)(z+x-y)(x+y-z)$ 18. $-(y-z)(z-x)(x-y)$ 19. $-(y-z)(z-x)(x-y)(x+y+z+3)$ 20. $(y-z)(z-x)(x-y)(x+y+z)$ 21. $(ax+by+cz)(by+cz-ax)(cz+ax-by)(ax+by-cz)$ 22. $(x+2y+3z)(2y+3z-x)(3z+x-2y)(x+2y-3z)$ 23. 4200 24. 249 25 1950

EXERCISE 79. [Pages 271, 272]

1. $(x+1)(x^2+1)$ 2. $(x+1)^2(x-1)$ 3. $(x+1)(x-1)^2$ 4. $(ab+c)(ac+b)$ 5. $(x-a)(x+b)(x^2-bx+b^2)$ 6. $(ax+by)(bx+ay)$ 7. $(x-z)(x+y+z)$ 8. $(x+a)(b-c)$ 9. $(x^2-ab)(2a-3b)$ 10. $(a-b)(a+b+c)$

11. $(2a-3b)(2a+3b+4c)$ **12.** $(ax-by)(ax+by+cz)$
13. $(x^2-yz)(x^2+yz+y^2)$ **14.** $(4x-5a)(4x+5a+3b)$
15. $(a+b)(a^2+ab+b^2)$ **16.** $(m-n)(m^2-mn+n^2)$
17. $(a-b)(a+b)^3$ **18.** $(x+y)(x-y)^3$ **19.** $(a+2)(a^2+3a+4)$
20. $(x-5)(x^2-12x+25)$ **21.** $(2a-3b)(4a+3b)(a+3b)$
22. $(x-y)(x-y-1)$ **23.** $(2a-b)(2a-b-3)$
24. $(x^2+a^2)(x-a)^2$ **25** $(a^2+2b^2)(a-b)(a-2b)$
26. $(a+2b)(a+b+c)$ **27.** $(x-3y)(x-y+z)$
28. $(m-2n)(m-3n+2p)$ **29.** $(a-3b)(a-7b+5c)$
30. $(x+4a)(2x-3a+4b)$ **31.** $(a-4b)(a-2b+3)$
32. $(3x+y)(x-3y+2)$ **33.** $(a-b-c)(a+b+c+1)$
34. $(x-2y+3z)(x+2y-3z+4)$ **35.** $(3x-4y-2z)$
$(3x-4y+2z-5)$ **36.** $(a+b)(a-b)(x+a)(x-a)(2x^2-3a^2)$
37. $(2x-3b)(x^2+ax-b)$ **38.** $(x+a)(x-a)(a+b)^2$
39. $(a-1)^2(2a^2-a+2)$ **40.** $(a-1)(a^2-6a+1)(a^2+3a+1)$
41. $(2x+2y+z)(x+2y+2z)$ **42.** $(x-y-z)(2x+3y+z)$
43. $(a^2+1)^2(a^4-7a^2+1)$ **44.** $(2x+y-3z)(2x-3y+3z)$
45. $(x-a)(x^2+ax+a^2)(x^2-ax+a^2)$ **46** $(x+1)(x+2)(x+4)$

EXERCISE 80. [Pages 275, 276]

1. $(x+1)(x+3)(x+4)$ **2.** $(x+2)(x+3)(x+4)$
3 $(x-1)(x-2)(x-3)$ **4.** $(x-2)(x+3)(x+4)$
5 $(x-1)(x^2-3x-2)$ **6** $(x+1)(x^2+4x-6)$
7. $(x-2)(x^2-4x+5)$ **8.** $(x-2)(x+2)(x^2-3x-5)$
9. $(x-1)(x+2)(x^2-4x+5)$ **10.** $(x+1)(x-3)(x^2-3x-2)$
11. $(x-2)(x+3)(x^2+4x-6)$ **12.** $(x+2)(x-4)(x^2-5x+7)$
13. $(x-5)(x^2-2x+3)$ **14.** $(x+3)(x^2-3x+4)$
15. $(x+2)(x-4)^2$ **16.** $(x-2)(2x^2+x+2)$
17. $(x+2y)(x^2-2xy-5y^2)$ **18.** $(a+3b)(a^2+ab-3b^2)$
19. $(a-2b)(5a^2+7ab+14b^2)$ **20.** $(2x-1)(4x^2+2x+3)$
21. $(x-1)(x+3)(2x+1)$ **22.** $(x+1)^2(x-2)$ **23.** $(a-b)$
$(2a^2+ab+b^2)$ **24.** $(x-1)(3x^2+11x+3)$ **25.** $(x+3y)$
$(x^2-3xy+3y^2)$ **26.** $(x+a-b)(x-a+2b)$ **27.** $\{x^2+(a+b)^2y^2\}$
$\{x+(a-b)y\}\{x-(a-b)y\}$ **28.** $\{a^2+(x+y)^2b^2\}\{a^2+(x-y)^2b^2\}$

29. $(a+2x-y)(a-x+2y)$ **30.** $(x+2a+b)(x-a+2b)$
31. $(x+3y-z)(x+y+z)$ **32.** $(2a+b-3c)(2a-3b+3c)$.
33. $(x^2+4x-3)(x^2+2x+3)$ **34.** $(a^2+ab-b^2)(a^2-5ab+b^2)$
35. $(2x^2-4x-3)(2x^2-6x+3)$ **36.** $(x-1)^2(x^2+1)$
37. $(a^2+3a-5)(a^2-3a+5)$ **38.** $(a-bx)(a-bx-cx^2)$
39. $(x^2y^2+xy-z+1)(x^2y^2-xy+z+1)$ **40.** $\{(y+z)x-y+z\}$
$\{(y-z)x+y+z\}$ **41.** $\{(a+b)x+(a-b)y\}\{(a-b)x+(a+b)y\}$
42. $(x^2-2x-1)(x^2-2x-4)$ **43.** $(a^2-3a+5)(a^2-3a+1)$
44. $(2x^2+3x-3)(2x^2+3x-4)$ **45.** $(x^2-xy+y^2)(x^2-4xy+y^2)$.
46. $(x^2-2x+4)(x^2-3x+4)$ **47.** $(a^2-2ab+2b^2)$
$(a^2-5ab+2b^2)$ **48.** $(x^2-3x+5)(x^2+7x+5)$.
49. $(a-b)^2(a^2+6ab+b^2)$ **50.** $(x^2+4x+10)(x^2+4x-2)$
51. $(x^2-3x-5)(x^2-3x-17)$ **52.** $(x-1)(x+8)(x^2+7x+30)$
53. $(x-3)(2x+3)(2x^2-3x+7)$ **54.** 0 **55.** 0 **56.** 0
57. 300 **58.** 5

EXERCISE 82. [Pages 299—301]

1. 179 **2.** 3 **3.** 65 **4.** $-8\frac{3}{4}$ **5.** $\frac{1}{a}(ad-bc)$
16. $5a^2-11a+15=0$ **17.** $a=0$, or $1\frac{1}{3}$ **18.** $2n$, where n is any positive integer **29.** $(b-c)(a-c)(a-b)(ab+bc+ca)$
36. $1+x+x^2+\ldots+x^{30}+x^{31}$ **38.** 11111111 **41.** $x^4-x^3y+x^2y^2-xy^3+y^4$ **42.** $x^5-x^4y+x^3y^2-x^2y^3+xy^4-y^5$
43. $x^6+x^5y+x^4y^2+x^3y^3+x^2y^4+xy^5+y^6$ **44.** $x^{14}-x^{12}y^2+x^{10}y^4-x^8y^6+x^6y^8-x^4y^{10}+x^2y^{12}-y^{14}$ **45.** $x^{15}+x^{14}y+\ldots+xy^{14}+y^{15}$ **46.** $p=12, a=\frac{1}{3}$ **49.** 0 **50.** 1

EXERCISE 83. [Pages 306, 307]

1. $2x-1$ **2.** $3x-2$ **3.** $2x+5a$ **4.** $x(3x+4)$ **5.** $3a-1$
6. $2a-3b$ **7.** x^2+x+1 **8.** x^2-xy+y^2 **9.** $x(2x^2+x+1)$.
10. x^2+3x+1 **11.** x^2+4x+1 **12.** $x^2+2ax+3a^2$
13. $x^2+3ax+5a^2$ **14.** $2a^2-3ax+7x^2$ **15.** $2-3x+5x^2$
16. $1+4x-7x^2$ **17.** $x^2(2x^2+3xa+4a^2)$ **18.** $2(a^2+5a+2)$
19. x^2+3x-2 **20.** x^2-3x+5 **21.** x^2+5x+1

22. x^2+2x+4 23. x^2+3x+5 24. $2(x^2-2ax+2a^2)$
25. $3x^2+2xy+4y^2$ 26 x^2+2x+3 27. $4a^2+2a-5$
28. x^2+2x+3

EXERCISE 84. [Page 310]

1. x^2-5x+6 2. $2x^3-17x+12.$ 3. x^2+3x+4
4. $3x^3-5x^2+7$ 5. $6x^2-11x+4$ 6. $2x^2+15x-8$
7. $3x^2+5x-1$ 8. $5x^2-3x-1$ 9. $2x^2+3x-1$
10. $3x^3-2x+1$ 11 x^2+x+2 12. x^2+3x-2

EXERCISE 85. [Pages 312, 313]

1. $x+4$ 2. $2x-1$ 3. $2x-3$ 4. $2x^2+1$
5 $3a-2b$ 6. $3a-5b$ 7. $3x-4$ 8. $2x^2-3$

EXERCISE 86. [Page 314]

1. $9x^4+30x^3-17x^2-76x+32$ 2. $18x^4+3x^3-109x^2-84x+32$ 3. $48x^5-64x^4-120x^3+160x^2+27x-36$
4. $45x^4-24x^3-123x^2+40x+80$ 5. $12x^4-14x^3-94x^2+63x+180$ 6. $12x^6+8x^5+25x^4+34x^3+15x^2+18x+8$
7. $32x^6-24x^5-8x^4+18x^3-48x^2+27x-18$ 8. $12x^6+24x^5+95x^4+118x^3+249x^2+144x+216$

EXERCISE 87. [Page 316]

1. $12x^4-100x^3+195x^2+70x-72$ 2. $6x^4-79x^3+273x^2-188x-96$ 3. $48x^4-92x^3-128x^2+157x-30$
4. $16x^8+40x^7+20x^6+38x^5-20x^4-32x^3-15x^2-9x+9$

EXERCISE 88. [Pages 318, 319]

1. $x+3$ 2. $\dfrac{x+3}{x+5}$. 3. $\dfrac{a+3b}{a-4b}$ 4. $\dfrac{x^2-ax+b^2}{x^2+ax-b^2}$.
5. $\dfrac{3x-2y}{2x+5y}$. 6. $\dfrac{1+2x-3x^2}{1-2x+3x^2}$ 7. $\dfrac{(x-1)^2}{x^2-3x+1}$.
8. $\dfrac{x^2+3x+5}{x^2+3x-5}$. 9. $\dfrac{x^2+3ax+7a^2}{2x^2-3ax+5a^2}$. 10. $\dfrac{2x+3}{3x+4}$.
11. $\dfrac{3x^2-ax-2a^2}{3x^2+ax-2a^2}$ 12 $\dfrac{2(a^2-5ab+7b^2)}{3(a^2+5ab+7b^2)}$.

13. $\dfrac{3(3x^2+4x+5)}{4(2x^2+3x+4)}$. **14.** $\dfrac{a(3a^2-b^2)}{2a^2-b^2}$. **15.** $\dfrac{4x(2x^2-3y^2)}{5y(3x^2-2y^2)}$.

16. $2(a+b+c)$ **17.** $1+xyz$ **18.** $\dfrac{z+x-2y}{4(y+z)}$.

19. 2 **20.** $\dfrac{7x-2y}{5x^2-3xy+2y^2}$

EXERCISE 89. [Pages 322—324]

1. $\dfrac{108x^4}{81x^4-y^4}$ **2.** $\dfrac{9ax(x+a)}{x^4-81a^4}$. **3.** $\dfrac{4ab}{(a-b)^2}$.

4. $\dfrac{6x^2-12}{x^4-5x^2+4}$ **5.** $\dfrac{6a^2x}{4x^4-5a^2x^2+a^4}$ **6.** $\dfrac{48a^3}{x^4-10a^2x^2+9a^4}$.

7. $\dfrac{2x}{x^4-1}$ **8.** $\dfrac{x-c}{(x-a)(x-b)}$. **9.** $\dfrac{4}{x^2-6x+5}$

10. $\dfrac{4}{x^2+14ax+13a^2}$ **11.** $\dfrac{2}{x+3}$. **12.** 0

13. $\dfrac{4x^3}{1+x^4+x^8}$. **14.** $\dfrac{12r^4}{x^6-64}$. **15.** $\dfrac{96ax^5}{16x^8-6561a^8}$.

16. $\dfrac{3}{(x+a)(x+4a)}$ **17.** $\dfrac{a-d}{(x+a)(x+d)}$ **18.** $\dfrac{6a-11}{(a-1)(a-2)(a-3)}$.

19. $\dfrac{1}{(x+2)^2}$. **20.** $\dfrac{5}{(x-3)(x-4)(x-5)}$. **21.** $\dfrac{1}{a-1}$.

22. 1 **23.** 0 **24.** 0 **25.** $\dfrac{x^4}{(x-a)(x-b)(x-c)(x-d)}$.

EXERCISE 90. [Pages 325—327]

1. $-x^2y^2z^2$ **2.** $\frac{1}{2}$ **3.** 1 **4.** $\dfrac{(b+c+a)^2}{2bc}$

5. $\dfrac{1+a^2}{1+a}$ **6.** $\dfrac{4a^4}{a^4-x^4}$. **7.** x **8.** $a-b$

9. $\dfrac{1}{3(x-2)}$. **10.** $-\dfrac{x^4+x^2y^2+y^4}{xy(x-y)^2}$. **11.** $\dfrac{adf+ae}{bdf+be+cf}$.

12. x^2 **13.** a^2+b^2 **14.** m **15.** $4xy$ **16.** 1

17. $\frac{1}{2}$ **18.** $\frac{2}{3}$ **19.** 1 **20.** a

EXERCISE 91. [Pages 335—340]

21. 0 24. 3 25. $\dfrac{a^4-10a^3b-6ab^3-b^4}{a^4+10a^3b+6ab^3-b^4}$ 26. 1

27. $\dfrac{a-b}{a+b}$. 28. 0 29. x^6+2 30. 1

31. $\dfrac{3(a+b)}{a-b}$. 32. 1 34. 0 35. 3

36. $x+y+z$ 37. $a^2+b^2+c^2$ 38. $a+b+c$

39. 0 42. 0 43. 1 44. 2

45. 1 46. 0 47. $\dfrac{1}{xyz}$.

48. $\dfrac{1}{(x-a)(x-b)(x-c)}$. 49. $\dfrac{x}{(x-a)(x-b)(x-c)}$.

50. $\dfrac{x^2}{(x-a)(x-b)(x-c)}$. 51. $\dfrac{x^2+hx+k}{(x-a)(x-b)(x-c)}$. 56. x^2

Miscellaneous Exercises. V

[Pages 340—345]

I.

1. (i) $(x^2+20x+95)^2-16$, (ii) $(x^2+5x+5)^2-16$
2. $3(z+x)(y+2z+x)(z+2x-y)$ 3. $18(a^2b^2+b^2c^2+c^2a^2)$
7. 0

II

1. 0 4. 0 5. $\dfrac{(a-b)^2}{ab}$. 6. $2a+3b+c$

7. $18x^4-45x^3+37x^2-19x+6$ 8. $(a-b)(b-c)(a-c)$

III

1. $x^5+10x^3+40x+\dfrac{80}{x}+\dfrac{80}{x^3}+\dfrac{32}{x^5}$. 3. 0 5. $2x-1$

$(x-3)(2x-1)(3x-2)$ 6. x^2-2x+3 7. $ab+bc+ca$

IV

1. 242 2. $(a-b)(2a-b)(a+b)(a+2b)(a^2+b^2)$. 3. 2528000

5. $\dfrac{a^2+b^2}{a^2-2ab-b^2}$ 7. $(x-5y)(x-3y)(x+2y)(x+7y)$, $(x-3y)(x+2y)(x+7y)$ 8. 0

V

3. 1 5. (i) $(3a^2-4ab+3b^2)(2a^2+17ab+2b^2)$, (ii) $(3x^2-7x+3)(4x^2-3x+4)$, (iii) $(ax^2+bx+a)(bx^2+cx+b)$

7. (i) $x-a$ (ii) $x-y-z$

VI

4. $(x+y)^4+z^4$ 5. $3(x^2+y^2+z^2)$

6. (i) $x^2+(2m-3)x-6m$; (ii) $x-3$ 7. $2x^2-3x+1$, $2x^6-3x^5-7x^4+28x^3-36x^2+20x-4$

VII

1. $x^2+2xy+y^2-1$ 2. x 4. (i) $a+b$, (ii) $\dfrac{1-x}{(1+x)(1+2x^2)}$.

5. $(5x+2y)^2+4(2x-5y)^2$, $p=5, q=2$ 6. $(2x-1)(3x-1)$, $(x-2)(2x-1)(3x-1)(2x+1)$ 7. -42

VIII

4. $(a+b+c+d)(a+b-c-d)(a-b-c+d)(a-b+c-d)$ 5. -1

6. 0 8. x^2+1. $(x^2-1)(x^2+1)^2$

EXERCISE 92. [Pages 348—350]

1. $-5\frac{1}{2}$ 2 $\dfrac{a^2+ab+b^2}{a+b}$. 3 $\frac{1}{3}(a+b+c)$

4. $\dfrac{a^2+b^2+c^2}{2(a+b+c)}$. 5. 2 6. 3 7. 4 8. 5

9. $1\frac{1}{2}$ 10. 4 11. 4 12. 7

13. 1 14. 4 15. 2 16. $\frac{12}{71}$ 17. 3

18. 2 19. $\frac{3}{2}$ 20. $2\frac{3}{4}$ 21. $26\frac{1}{3}$. 22. 13

23. $55\frac{1}{2}$ 24. $-\frac{19}{78}$ 25. $-\frac{49}{114}$ 26. $-\frac{24}{7}$ 27. 15.

28 $\frac{31}{47}$ **29.** $\frac{4}{5}$ **30.** $\dfrac{ab(a+b-2c)}{a^2+b^2-ac-bc}$ **31.** $\dfrac{(a^2-ab+b^2)c+ab}{ab(c+1)}$

32. $\dfrac{bn-am}{m-n}$ **33.** $\dfrac{a^2-bc}{b+c-2a}$ **34.** $\dfrac{3ab-a^2-b^2}{a+b}$ **35.** $3a$

EXERCISE 93. [Pages 352, 353]

1. $\frac{3}{2}$ **2.** -3 **3** $-\frac{46}{63}$ **4.** 2 **5.** 1 **6.** 2
7. $\frac{7}{9}$ **8.** $-\frac{11}{7}$ **9.** 2 **10.** $\frac{1}{4}$ **11.** $\frac{5}{3}$ **12.** $1\frac{8}{11}$
13 $\frac{1}{5}$ **14.** $\frac{7}{8}$ **15.** $4\frac{1}{2}$ **16.** 6 **17.** 7 **18.** $4\frac{1}{2}$
19. $-\frac{4}{3}$ **20.** 1 **21.** $-\frac{5}{6}$ **22.** $3\frac{1}{2}$

EXERCISE 94. [Pages 355, 356]

1. 24 **2.** $-b$ **3.** $-\frac{3}{4}$ **4.** 2 **5.** 7
6 $\dfrac{a^2+b^2}{a+b}$. **7.** $\dfrac{ab}{a+b}$ **8.** $\dfrac{ab(c+d)-cd(a+b)}{ab-cd}$ **9.** 2
10 $\dfrac{3}{2a^2}$. **11.** 4 **12** $\dfrac{a^2+b^2}{a+b}$ **13.** 3
14. 2 **15.** $\dfrac{ab}{a-b}$ **16.** 25 **17.** 3
18. $\dfrac{2(a^2+b^2)}{a-b}$ **19.** 6 **20.** $\frac{1}{2}(a-b)$

EXERCISE 95. [Pages 364—368]

1. $16\frac{4}{11}$ minutes past 3 **2.** $27\frac{3}{11}$ minutes past 5 **3.** (i) $5\frac{5}{11}$ minutes past 7, (ii) $21\frac{9}{11}$ and $54\frac{6}{11}$ minutes past 7, (iii) $38\frac{2}{11}$ minutes past 7 **4.** (i) at $5\frac{5}{11}$ minutes past 7, (ii) at $16\frac{4}{11}$ minutes past 6 **5.** $\dfrac{pa}{p+q}$ miles **6.** 8 miles from the starting place of the faster walker 6 hours **8.** 36 minutes **9.** $3\frac{1}{2}$ and $4\frac{1}{2}$ miles per hour **10.** 160 **11.** £6 **12.** 300 **13.** Greyhound, 960 hare, 1200 **14.** 180 **15.** 20 shillings, 5 shillings **16.** 40 **17.** 76 lbs of gold and 30 lbs of silver. **18.** 4 hours and 6 hours **19.** 42 years **20.** $6\frac{2}{3}$ oz from the 1st bar $13\frac{1}{3}$ oz from the 2nd **21.** £150 8*s* 4*d*, £156 13*s* 4*d*

22. 11 pice, each man of the 1st set 6 pice of the 2nd set 5 pice, of the 3rd set 4 pice, and of the 4th set 4 pice

23. 189 **24.** 25 oz 8*s* per oz **25.** 7*s* . 11*s* 8*d*

26. 2080 **27.** $\frac{3}{4}d$ each, 512 **28.** 12 **29.** 654

30. 1504 **31.** 80 **32.** 736 **33.** 4550

EXERCISE 96. [Pages 373 374]

1. $x=1$ $y=2$ **2.** $x=2,$ $y=3$ **3.** $x=3$ $y=4$

4. $x=4,$ $y=5$ **5.** $x=5$ $y=6$ **6.** $x=6,$ $y=7$

7. $x=7$ $y=8$ **8.** $x=8$ $y=9$ **9.** $x=4,$ $y=2$

10. $x=5$ $y=3$ **11.** $x=7$ $y=4$ **12.** $x=5,$ $y=8$

13. $x=8,$ $y=12$ **14.** $x=6,$ $y=14$ **15.** $x=8,$ $y=18$

16. $x=8,$ $y=9$ **17.** $x=12$ $y=16$ **18.** $x=21,$ $y=12$

19. $x=21,$ $y=24$ **20.** $x=18,$ $y=28$

21. $x=99,$ $y=15$ **22.** $x=10$ $y=8$

23. $x=3,$ $y=7$ **24.** $x=4$ $y=7$

25. $x=3,$ $y=5$ **26.** $x=1$ $y=2,$ $z=3$

27. $x=2,$ $y=-3,$ $z=1$ **28.** $x=3$ $y=4,$ $z=2$

29. $x=2$ $y=6,$ $z=4$ **30.** $x=1,$ $y=3$ $z=5$

31. $x=2$ $y=3$ $z=4$ **32.** $x=3$ $y=6$ $z=9$

33. $x=4,$ $y=10,$ $z=14$ **34.** $x=8$ $y=12$ $z=20$

35. $x=3$ $y=4$ $z=5.$

EXERCISE 97. [Pages 377 378]

1. $x=1$ $y=2$ $z=3$ **2.** $x=2,$ $y=3$ $z=4$

3. $x=2,$ $y=3$ $z=4$ **4.** $x=2$ $y=3.$ $z=4$

5. $x=3,$ $y=2$ $z=1$ **6.** $x=3$ $y=2$ $z=1$

7. $x=4,$ $y=3,$ $z=2$ **8.** $x=4,$ $y=5,$ $z=6$

9. $x=7$ $y=5.$ $z=3$ **10.** $x=1$ $y=-2,$ $z=3$

11. $x=3$ $y=2,$ $z=5$ **12.** $x=3$ $y=\frac{1}{2}.$ $z=\frac{2}{3}$

13. $x=10,$ $y=20.$ $z=5$ **14.** $x=2.$ $y=-3.$ $z=4$

15. $x=5.$ $y=6.$ $z=7$ **16.** $x=2.$ $y=4,$ $z=6$

17. $x=2$ $y=5.$ $z=10$ **18.** $x=12,$ $y=12,$ $z=12$

19. $x=6,$ $y=12$ $z=8$ **20.** $x=\frac{1}{2},$ $y=\frac{1}{3},$ $z=\frac{1}{4}$

21. $x=7$ $y=10$ $z=9$ **22.** $x=1,$ $y=-2$ $z=3.$

23. $x=\frac{b^2+c^2-a^2}{2bc}$, $y=\frac{c^2+a^2-b^2}{2ca}$, $z=\frac{a^2+b^2-c^2}{2ab}$.

24. $x=1, y=2, z=3$ **25.** $x=-28, y=10, z=9$

EXERCISE 98. [Pages 381, 382]

1. $x=\frac{a}{2}$, $y=\frac{b}{2}$, $z=\frac{c}{2}$. **2.** $x=\frac{2}{a+b-c}$, $y=\frac{2}{a-b+c}$, $z=\frac{2}{b+c-a}$. **3.** $x=\frac{2abc}{ab+ac-bc}$, $y=\frac{2abc}{bc+ab-ac}$, $z=\frac{2abc}{ac+bc-ab}$

4. $x=\frac{a^2+b^2}{a^2-b^2}\cdot c$ $y=\frac{a^2+b^2}{2ab}\cdot c$ **5.** $x=2, y=4, z=6$

6. $x=5, y=3, z=1$ **7.** $x=12, y=10, z=8$

8. $x=13, y=8, z=9$ **9.** $x=4, y=5, z=7$

10. $x=\frac{b(2a-b)}{a-b}$, $y=\frac{a(2b-a)}{b-a}$ **11.** $x=\frac{bc}{(b-a)(c-a)}\cdot A$ $y=\frac{ca}{(c-b)(a-b)}A$, $z=\frac{ab}{(a-c)(b-c)}\cdot A$

12 $x=\frac{1}{(b-c)(a-c)}$, $y=\frac{1}{(c-b)(a-b)}$, $z=\frac{1}{(a-b)(a-c)}$.

13. $x=\frac{a^2bc}{(a-b)(a-c)}$, $y=\frac{b^2ca}{(b-c)(b-a)}$, $z=\frac{c^2ab}{(c-a)(c-b)}$.

14. $x=abc, y=ab+bc+ca, z=a+b+c$ **15.** $x=b-c, y=c-a$ $z=a-b$. **16.** $a_3(b_1c_2-b_2c_1)+b_3(c_1a_2-c_2a_1)$ $+c_3(a_1b_2-a_2b_1)=0$ **17.** $a=6$ **18.** $w=4, x=12, y=5, z=7$ **19.** $x=5$ $y=4, z=3, w=2$ $t=1$ **20.** $x=ab$ $y=bc$ $z=ac$

EXERCISE 99. [Pages 389—392]

1. 375 **2.** 50 lbs, 28*s* per lb **3.** *A*, 14*s* *B*, 19*s* **4.** 20. 30, 60 **5.** 3*s* 6*d*, 4*s* 2*d* **6.** *A*, $\frac{pm}{p+n-m}$, *B*, $\frac{pm}{m-n}$ days **7.** *A*, Rs 980, *B*, Rs 1540, *C*, Rs 2380 **8.** 8 hours **9.** 720 miles **10.** 4 and 3 gallons **11.** 253 **12.** 3 half-crowns, 8*s*, 9 six-pences **13.** 20 persons, 6*s* **14.** Each of the equal cocks in 32 hours, and the other in 24 **15.** 8*s* and 5*s*. respectively **16.** 75 and 25 quarts **17.** 6 qrs of wheat 10 qrs of barley **18.** 45 and $22\frac{1}{2}$ miles per hour **19.** 20 bushels of rye, and 52 of wheat **20.** 21 guineas and

21 crowns *at first*, 9 guineas and 12 crowns *left* **21.** $2\frac{1}{2}$ miles per hour **22.** A, 5, B, 6 minutes **23.** 10 and 12 miles per hour **24.** $\dfrac{b(n-1)}{a-c}$ miles per hour **25.** 100 miles

EXERCISE 100. [Pages 398, 399]

1. $x=5, y=4$ **2.** $x=7, y=-5$ **3.** $x=8, y=6$
4. $x=9, y=11$ **5.** $x=10, y=13$
6. [Take ten times the side of a small square as the unit of length] $x=1\cdot2$ **7.** $x=7$ **8.** $x=7$ **9.** 9 **10.** 4
11. $(-6, 4)$, $(8, 2)$, $(6, 8)$, area=40 units. **12.** $(5, 4)$
13. (i) $(3, 0)$, $(0, 3)$, $(-3, 0)$, $(0, -3)$, area=18 units (ii) $(1, 5)$; $(12, 5)$, $(12, 10)$, $(1, 10)$, area=55 units (iii) $(3, 0)$, $(8, 0)$, $(0, 5)$, $(0, 12)$, area 40·5 units **14.** (i) $(0, 0)$, $(5, 0)$, $(0, 6)$, area=15 units (ii) $(2, 1)$, $(2, 4)$, $(5, 1)$, area=4·5 units (iii) $(4, 6)$, $(-4, 2)$, $(2, -4)$, area=36 units
15. $\left.\begin{array}{l}x=1\\y=1\end{array}\right\}$ **16.** $\left.\begin{array}{l}x=\ \ 7\\y=-5\end{array}\right\}$ **17.** $\left.\begin{array}{l}x=\ 9\\y=11\end{array}\right\}$

EXERCISE 101. [Pages 406—408]

1. 13 as 3 pies, 2 seers 11 chattacks

2. Re 1, 9 as 6 p, 19

3. $3\frac{1}{4}$ hours; 19 miles

4. $8\frac{5}{8}$ feet, $4\frac{1}{2}$ cubits

5. $2\frac{1}{2}$ hours after A starts, $7\frac{1}{2}$ miles from the place of starting

6. 4 hours after starting, 12 miles from A

7. Re 1 3 as, 39 **8** 5

11. At 4-30 P M $13\frac{1}{2}$ miles from B

12. Rs 434

13. 16·4 minutes after 3

14. Rs. 3265, Rs 113 7 as **15.** 6 hours 59·4 minutes, 10·8 miles from Calcutta

EXERCISE 102. [Pages 411, 412]

1. $\sqrt[7]{a^5}$ 2. $\dfrac{1}{\sqrt{x^3}}$ 3. $3\sqrt[5]{x^4}$ 4. $\dfrac{3}{\sqrt[5]{x^2}\times\sqrt{a}}$.

5. $\dfrac{8}{\sqrt[3]{m^8}}$. 6. $\dfrac{\sqrt[4]{a^5}}{3\sqrt[5]{x^4}}$ 7. $\dfrac{1}{2\sqrt[6]{x}}$ 8. $\sqrt[5]{x^{a+2}}$

9. $\sqrt[2m]{a^{11}}$ 10. $\sqrt[a]{x^4}$ 11. $x^{\frac{7}{3}}$ 12. $\dfrac{1}{a^{\frac{3}{2}}}$ 13. $x^{\frac{2}{3}}$

14. $a^{\frac{2}{5}}$ 15. $x^{\frac{3}{2}}$ 16. $a^{\frac{3}{4}}$ 17. $\frac{1}{8}$ 18. 4

19. 27 20 32 21. $\frac{1}{27}$ 22. 36 23. $\frac{1}{25}$

24. 81 25. 36 26. x^{-m}

EXERCISE 103. [Pages 414, 415]

1. a^{-6} 2. $a^{-\frac{1}{2}}b^{\frac{5}{8}}$ 3. ab^6 4. $a^{-8}b^{-3}$

5. a^8b^6 6. $x^{-\frac{9}{2}}y^4$ 7. $x^{\frac{5}{32}}$ 8 a^{-1}

9. y 10. $\frac{4}{9}x^2a^2$ 11. $\frac{9}{16}x^{-2}a^{-2}$ 12. $a^{\frac{1}{2}}b^{\frac{1}{3}}c^{\frac{2}{3}}$.

13. $a^{-1}b^{\frac{2}{3}}c^{\frac{1}{6}}$ 14. $a^{\frac{3}{2}}b^{-\frac{1}{3}}c^{\frac{1}{2}}$ 15. a^4b^2

EXERCISE 104. [Pages 419—421]

1. $x-2x^{\frac{1}{2}}+1$ 2. $a-27b$. 3. $1+a^2b^{-2}+a^4b^{-4}$

4. $x^2+6xz^{\frac{1}{3}}-4y+9z^{\frac{2}{3}}$ 5. $x^{-2}+x^{-1}y^{-1}+y^{-2}$

6. $a+a^{\frac{1}{3}}-1+a^{-\frac{1}{3}}+a^{-1}$ 7. $x+y+z-3x^{\frac{1}{3}}y^{\frac{1}{3}}z^{\frac{1}{3}}$

8. $a^{2m}-9b^{2n}+12b^nc^p-4c^{2p}$ 9. a^3-64b^2

10. $a+a^{\frac{3}{4}}x^{-\frac{1}{4}}-a^{\frac{1}{4}}x^{-\frac{3}{4}}-x^{-1}$ 11. $x-x^{\frac{1}{2}}$.

12. $2x^{-2}+4x^{-1}+2$ 13. $y+x^{\frac{1}{2}}y^{\frac{1}{2}}+x$ 14. $a+a^{\frac{1}{2}}b^{\frac{1}{2}}-b$

15 $x^{2n}-1+x^{-2n}$ 16. $4x-2x^{\frac{1}{2}}y^{-\frac{1}{2}}+2x^{\frac{1}{2}}z^{\frac{1}{3}}+y^{-1}+y^{-\frac{1}{2}}z^{\frac{1}{3}}+z^{\frac{2}{3}}$.

17. $x^{\frac{9}{4}}-x^{\frac{15}{8}}a^{\frac{3}{8}}+x^{\frac{9}{8}}a^{\frac{9}{8}}-x^{\frac{3}{8}}a^{\frac{15}{8}}+a^{\frac{9}{4}}$

18. $x^{2^n}-a^{2^n}$ 19. $x^{2^{n-1}}-y^{2^{n-1}}$ 20. a^{m-1}

21 $x^{\frac{3}{4}}+3x^{\frac{1}{2}}-1$ 22. $x^{\frac{3}{2}}+xy^{-\frac{1}{2}}-2x^{\frac{5}{4}}y^{-\frac{1}{4}}-2x^{\frac{1}{2}}y^{\frac{1}{4}}+2x^{\frac{3}{4}}y^{\frac{1}{2}}+y$

23. $x^n+x^{\frac{n}{2}}a^{\frac{n}{2}}+a^n$ 24. $x^{\frac{2}{3}}-4x^{\frac{5}{6}}+4x+2x^{\frac{7}{6}}-4x^{\frac{4}{3}}+x^{\frac{5}{3}}$

25. $a^{\frac{2}{3}}x^{-\frac{2}{3}}+a^{\frac{1}{3}}x^{-\frac{1}{3}}+a^{-\frac{1}{3}}x^{\frac{1}{3}}+a^{-\frac{2}{3}}x^{\frac{2}{3}}$

26. $\frac{1}{\sqrt{a}}+\frac{1}{\sqrt{b}}$. 27. $\frac{2x+36x^{\frac{1}{3}}y^{\frac{2}{3}}}{x-27y}$. 28. $\frac{x+a}{x^2+3xa+a^2}$.

29. 1 30 $x^{\frac{1}{4}}y^{\frac{1}{4}}-x^{-\frac{1}{4}}y^{\frac{3}{4}}$ 31. 1 32. 3

33. 5 34. 2 35. 4 36. $x=1,\ y=2$

37. $x=2, y=3$ 38. $x=1,\ y=3$

39. $x=1, y=2\ z=3$ 40. $x=2, y=4, z=6$

EXERCISE 105. [Page 422]

1. $\sqrt{45}$ 2. $\sqrt[3]{24}$ 3. $\sqrt[4]{96}$ 4. $\sqrt[4]{1280}$

5. $\sqrt[n]{a^n b}$ 6 $\sqrt[a]{x^{3a}y}$ 7. $\sqrt[5]{a^{20}b^2}$

EXERCISE 106. [Page 423]

1. $3\sqrt{2}$ 2. $4\sqrt{5}$ 3. $5\sqrt[3]{2}$ 4. $2\sqrt[5]{4}$ 5. $3\sqrt[4]{5}$

6. $7\sqrt[3]{4}$ 7. $5\sqrt[4]{3}$' 8. $a^2\sqrt[3]{b}$ 9. $x^4\sqrt[n]{a}$ 10. $-8\sqrt[3]{5}$

11. $-4ab\sqrt[3]{3b}$ 12. $5a^2x\sqrt[3]{4ax}$

EXERCISE 107. [Page 423]

1. $7\sqrt{3}$ 2. $7\sqrt{2}$ 3. $8\sqrt{5}$ 4 $2\sqrt{2}$ 5. $\sqrt[3]{2}$

6. $5\sqrt[4]{5}$ 7. $\sqrt[4]{3}$ 8. $3\sqrt{3}$ 9. $6\sqrt{5}$ 10. 0 11. 0

12. $17\sqrt[3]{2}$ 13. $(7x+y)\sqrt{5x}$ 14. $(x^2-2y^2+3z^2)\sqrt[3]{a}$

15. $4a\sqrt[4]{2x}$

EXERCISE 108. [Pages 424, 425]

1. $\sqrt[6]{27}$ and $\sqrt[6]{4}$ 2. $\sqrt[12]{256}$ and $\sqrt[12]{125}$ 3. $\sqrt[15]{8}$ and $\sqrt[15]{243}$ 4. $\sqrt[12]{27}$ and $\sqrt[12]{25}$ 5. $\sqrt[24]{256}$ and $\sqrt[24]{216}$

6. The latter 7. The former 8. The former

9. $\sqrt[3]{4}$, $\sqrt[4]{6}$, $\sqrt{2}$ 10. $\sqrt[6]{10}$, $\sqrt[4]{3}$, $\sqrt[12]{25}$

EXERCISE 109. [Page 426]

1. $5\sqrt{2}$. 2 $4\sqrt{3}$ 3. 9 4. $3\sqrt{10}$ 5. 30 6. 5

7. $3ax\sqrt[3]{6x}$ 8. $\sqrt[6]{864}$ 9. $\sqrt[6]{288}$ 10. $4\sqrt[6]{2}$

11. $9\sqrt[6]{3}$ 12. $\sqrt[12]{72}$ 13. $\sqrt[8]{27}$ 14. $\sqrt[1]{32}$

15. $\sqrt[12]{1024}$ 16. $40\sqrt{3}$ 17. $288\sqrt{2}$ 18. $480\sqrt[3]{3}$

19. $210aba\sqrt[3]{x}$ 20. $2\sqrt{\frac{2}{3}}$ 21. $\frac{1}{3}$ 22. $\sqrt[3]{4}$
23. $\sqrt[6]{\frac{2}{3}}$ 24. 577 25. 1 341 26. 3 535
27. 26 832

EXERCISE 110. [Pages 427 428]

1. $a\sqrt{b}+b\sqrt{a}$ 2. $a-b$ 3. $6a-10\sqrt{a}$ 4. $16x-9y$
5. $6x-54$ 6. $6+\sqrt{10}$ 7. $7+4\sqrt{6}$ 8. $6-6\sqrt{5}$
9. $2+6\sqrt{2}$ 10. $5+3\sqrt[3]{12}+3\sqrt[3]{18}$ 11. $2x-2\sqrt{x^2-a^2}$
12. $182+80\sqrt{3}$ 13. $83+12\sqrt{35}$ 14 $2a^2-2\sqrt{a^4-4b^4}$
15. $29x^2-21y^2+20\sqrt{x^4-y^4}$

EXERCISE 111. [Page 430]

1. $\frac{23-3\sqrt{21}}{10}$ 2. $5+2\sqrt{6}$ 3 $24+17\sqrt{2}$
4. $9+2\sqrt{15}$ 5. $\frac{a+\sqrt{a^2-x^2}}{x}$ 6. $x^2-\sqrt{x^4-1}$
7. $\frac{1}{4}(2+\sqrt{2}-\sqrt{6})$ 8. 5 828 9. 6 464 10. 5 414
11. 3 650 12 6 854 13. 504 14. $2x$ 15 $\sqrt{3}(1+\sqrt{2})$
16. $2+\sqrt{3}$ 17. $\frac{1}{3}(\sqrt{30}+2\sqrt{3}-3\sqrt{2})$ 18. 198
19. $4x\sqrt{x^2-1}$ 20. $2x^2$ 21. $\frac{\sqrt[3]{9}-\sqrt[3]{6}+\sqrt[3]{4}}{5}$
22 $\sqrt[3]{16}+\sqrt[3]{12}+\sqrt[3]{9}$

EXERCISE 112. [Pages 434 435]

1. $\sqrt{3}-1$ 2. $\sqrt{3}+2$ 3. $3-\sqrt{2}$ 4. $\sqrt{5}+\sqrt{3}$
5. $3-\sqrt{5}$ 6. $5+\sqrt{3}$ 7. $4-\sqrt{5}$ 8. $3+2\sqrt{2}$
9. $6+\sqrt{5}$ 10. $5-2\sqrt{3}$ 11 $2\sqrt{7}+\sqrt{3}$
12. $3\sqrt{5}-2\sqrt{7}$ 13. $2\sqrt{11}+\sqrt{3}$ 14 $\sqrt{[illegible]}-\sqrt{\frac{1}{2}}$ 15. $\sqrt{[illegible]}-\sqrt{\frac{3}{2}}$
16. $\sqrt[4]{2}(\sqrt{2}-1)$ 17. $\sqrt[4]{2}(\sqrt{3}-1)$ 18. $\sqrt[4]{3}(1+\sqrt{2})$
19. $\sqrt[4]{5}(\sqrt{3}+\sqrt{2})$ 20 $\sqrt{2}$ 21. 1, or [illegible] $\sqrt{3}-2$
22 b 23 $x+\sqrt{a^2-x^2}$ 24. $\sqrt{a+b}+\sqrt{a-b}$.
25 $\sqrt{a+\frac{1}{2}x}+\sqrt{\frac{1}{2}x}$ 26. $\sqrt{x+2}+\sqrt{x-3}$ 27. $\sqrt{x+y}+\sqrt{z}$

EXERCISE 113. [Pages 438, 439]

1. 9 **2.** 3 **3.** 16 **4.** $\frac{3}{4}$ **5.** $\frac{9}{20}$ **6.** 25

7. 8 **8.** 25 **9.** 2 **10.** $\frac{a}{4}$ **11.** $\frac{(b-a)^2}{2b}$. **12.** 5

13. 9 **14.** 7 **15.** 5 **16.** 6 **17.** 3 **18.** $\frac{5}{8}$ **19.** 81

20. $x=\frac{81}{a}$. **21.** $\frac{1}{a}\left(b+\frac{c^2}{c-1}\right)^2$. **22.** 5 **23.** $\frac{17a}{8}$. **24.** $\frac{1}{5}a$

25. 36 **26.** $\frac{2a^2-2ab+b^2}{2(b-a)}$. **27.** 4 **28.** $\frac{16}{25}$ **29.** $4\frac{1}{2}$.

30. $\frac{24}{25}$ **31.** $\frac{ab^{\frac{2}{3}}}{a^{\frac{2}{3}}-b^{\frac{2}{3}}}$. **32.** $\frac{7}{12}$ **33.** 1 or -1 **34.** $\frac{2a}{\sqrt{5}}$.

35. $\frac{41a^2}{40b}$. **36.** 7 **37.** 5 **38.** $\frac{b^2-4a^2}{4a}$. **39.** 5 **40.** 4.

EXERCISE 114. [Pages 444, 445]

1. $2xz+3y$ **2.** x^2-2x+3 **3.** x^3-x+1 **4.** $2x^2-3x+4$

5. $2x^2+2ax+4b^2$ **6.** $3x^2-\frac{1}{3}xy+3y^2$ **7.** $x^2-x+\frac{1}{4}$

8. $7x^2-\frac{x}{5}+3$ **9.** $x^2-\frac{x}{2}+\frac{2}{x}$. **10.** $\frac{a^2}{2}+\frac{a}{x}-\frac{x}{a}$.

11. $\frac{a}{2b}-1-\frac{2b}{a}$. **12.** $\frac{3a}{x}-\frac{1}{5}+\frac{2x}{3a}$. **13.** $2x^2-2xy^2-y^4$.

14. $\frac{7x}{y}-3-\frac{y}{7x}$. **15.** $\frac{x}{y}-\frac{1}{2}-\frac{y}{x}$ **16.** $\frac{2x}{7y}-5+\frac{3y}{4x}$

17. $x-x^{\frac{1}{2}}+1$ **18.** $x^{\frac{5}{6}}-2x^{\frac{1}{2}}-x^{\frac{1}{6}}$ **19.** $ax^{-1}+1+a^{-1}x$

20. $x^{\frac{3}{4}}-x^{\frac{1}{2}}y^{-\frac{1}{4}}+y^{\frac{1}{2}}$ **21.** $\frac{3x^{\frac{3}{2}}}{2}-\frac{5xy^{\frac{1}{2}}}{3}+\frac{2x^{\frac{1}{2}}y}{5}$. **22.** a^m-2a^n

23. $3a^m+a^{2m+1}-5c^{m-2}$

EXERCISE 115. [Pages 447, 448]

1. $5xy-4$ **2.** $7ax^2-3b^2$ **3.** $7a^3b^4+9a^4b^3$.

4. $\frac{1}{2}x^4y^2-\frac{1}{5}x^3y^5$ **5.** $\frac{5ab}{2}-\frac{c^2}{3}$. **6.** $a+b+c$

7. $a-b+c$ **8.** $2a-b-3c$ **9.** $a^2+2b^2-3c^2$.

10. $2a^2-3b^2+5c^2$ **11.** $x+\frac{a}{3}-\frac{b}{2}$. **12.** $x-2-\frac{1}{x}$.

13. $x^2+1+\frac{1}{x^2}$. 14. $\frac{a}{b}+1+\frac{b}{a}$. 15. $\frac{x}{y}-\frac{1}{\sqrt{2}}+\frac{y}{x}$.
16. $\frac{3x}{a}-1+\frac{a}{3x}$ 17. $x+2+\frac{1}{x}$. 18. $a^{\sqrt{2}}-a^{-\sqrt{2}}$
19. $a-b+c-d$ 20. a^2+b^2 21. $a^2-b^2+c^2-d^2$
22. $a^2+a-\frac{1}{2}$ 23. $2a(b+c)+2bc$

EXERCISE 116. [Page 451]

1. $x+9$ 2. $3x-8$ 3. $4a-3b$ 4. x^2-3x+2
5. $2x^2+x-3$ 6. $1-3x^2+2x^4$ 7. $2x^2-3cx+c^2$

EXERCISE 117. [Pages 455, 456]

1. The latter 2. The latter 3. The former
4. The former 5. The latter 6. a d 7. 1 4
8. 1 1 9. 75 8 10. 28 27
11. 5 7 12. 3 4 13. 63 and 72 14. 85 and 51
15. 28 and 35 16. 42 and 54 17. -15 18. 35
19. -17 20. $\frac{ad-bc}{c-d}$. 23. 76 75
24. 1772 1771 25. B

EXERCISE 118. [Pages 457, 458]

1. 4 2. 18 3. $37\frac{1}{2}$ 4. 36 5. 20
6. 60 7. 20 8. 6 9 14 10. 18

EXERCISE 119. [Pages 462, 463]

1. $x=9$, $y=6$ 2. $x=25$, $y=9$ 3. $x=56$, $y=30$
4. $\frac{1}{3}a$ 5. $\frac{5}{8}$ 6 $\frac{3}{4}$ 7. $\frac{4}{81}$ 8. $\frac{1}{5}$ 9. $2\frac{7}{9}$
10. $\sqrt{2ab-b^2}$ 11. $a\left\{1-\frac{16b^2}{(1+b)^4}\right\}$. 15. 2

EXERCISE 121. [Pages 468—470]

26. 0

EXERCISE 122. [Pages 474, 475]

1. $b^2c^2=a^2d^2$ 2. $b^3c^2=a^3d^2$ 3. $p^3n^4=q^3m^4$
4. $ad^2-bd+c=0$ 5. $lb^2-mab+a^2n=0$

6. $(bn-cm)(am-bl)=(cl-an)^2$. 7. $ab=1$

8. $35pq=6$ 9. $(b_1c_2-b_2c_1)(a_1b_2-a_2b_1)^2=(c_1a_2-c_2a_1)^3$

10. $(b_1c_2-b_2c_1)^2(a_1b_2-a_2b_1)=(c_1a_2-c_2a_1)^3$

11. $(b_1c_2-b_2c_1)^3(a_1b_2-a_2b_1)=(c_1a_2-c_2a_1)^4$

12. $(an^2-bn+cm)(am^2-an+b)=(c+amn)^2$

13. $(c^2+3ab)(b^2-2ab-ac)=(3a^2-2ac+bc)^2$

14. $a^2+b^2=m^2+n^2$ 15. $(ab_1+bc_1)^2+(a_1b+b_1c)^2$

$=(cc_1-aa_1)^2$ 16. $a^2n+b^2l=abm$

17. $ab+bc+ca+2abc=1$. 18. $a+b+c+abc=0$

19. $a^2+b^2+c^2-abc=4$ 20. $d^2(a+b+c)+abc=0$

21. $x^2+y^2+z^2+2xyz=1$

EXERCISE 123. [Page 477]

4. $x=a, y=b$ 5. $x=1, y=1$ 6. $x=a, y=a$
7. $x=1, y=1, z=0$ 8. $x=a, y=b$

EXERCISE 125. [Page 480]

1. 8 2. 7 3. 6 4. $\frac{49}{8}$

5. 33 6. 2 7. $-\frac{1}{8}$ 8. $-\frac{1}{16}$

9. $1\frac{11}{12}$ 10. $\frac{7}{8}$ 11. 16, 16

Miscellaneous Exercises VI.

[Pages 492–507]

I.

1. $1\frac{2}{3}$ 2. 0 3. $5b(a+b)$ 4. $2x^2-4xy+5y^2$

5. $\dfrac{b^3}{(a+b)^3}$. 6. $\dfrac{ab}{b-a}$. 8. $5+\sqrt{6}$

II

1. 21 2. $4x^2-6x-1$ 3. 12 4. $\dfrac{3\sqrt{2}}{5}$.

5. x^2-3x+2 6. $\frac{1}{5}$ 7. 11

III.

1. -30 2. $\dfrac{4x^2}{1-x^4}$. 3. $(a+b-3c)(a-b+3c)$

4. $x-a$ 5. $(x-1)(x-2)(x-3)$ 6 $\dfrac{x(x+2)}{x^2-2x+4}$.

7. $\frac{1}{3}$

IV

1. $\dfrac{y^2}{x^2}$. 2. $x^6+x^5y-x^3y^3+xy^5+y^6$ 3. (i) $(x-1)(x+1)^2$, (ii) $(a+1)(a-1)(b+1)(b-1)$. 4 p494 5. $(64x^6-729)(3x+2)$

6. $-\frac{6}{7}$ 7. $x=a^2b,\ y=ab^2$

V

1. 1 2. $a^2(b-c)+b^2(c-a)+c^2(a-b)=-(b-c)(c-a)(a-b)$

3. $\dfrac{9(a^2+3)}{a(a^2+27)}$ 4. $\dfrac{4\sqrt{y}}{x}-4+\dfrac{x}{\sqrt{y}}$. 6. $\dfrac{34\sqrt{5}-18}{11}$.

7. $x=3,\ y=1$

VI

1. 1 2. $b^2-a^2+\dfrac{b^4}{a^2}-\dfrac{a^4}{b^2}$. 3. $x^2+(a-b)x-ab$

5. $\dfrac{5x^2-4x-8}{3x^2+4x+24}$. 6. $x=\frac{1}{4},\ y=\frac{1}{3}$ 7. $x=3,\ y=5,\ z=7$

VII

1. $2x^3y^{-3}-3x^4y$ 2. ae^x+e^x+a+1 4. $\dfrac{ax+by}{ax-by}$.

5. 7 7. 80, 128

VIII

2. (i) $(b+c-a)(b+c-5a)$, (ii) $(x-a)(x+2y+a)$

3. $\dfrac{a+b}{(a-b+c)(b+c-a)}$. 5. -6 6. $2x^2-3x^{-1}+4x^{-4}$

7. $x=7\frac{1}{2},\ y=3\frac{1}{3},\ z=1\frac{1}{5}$

IX

1. -20 2. $\dfrac{1}{x^2-1}$. 3. $(a-b+1)(a^2+b^2+1+ab-a+b)$

4. 6 6. $x=16, y=4$ 7. $27\frac{3}{11}$ minutes past 8

X

1. $9a^2+4b^2+9c^2-6bc+9ca+6ab$ 2. x^2+2x+3.

3. $\{(a+b)x+(a-b)y\}\{(a-b)x+(a+b)y\}$ 4. $\dfrac{a^2-b^2}{a^2+b^2}$.

6. 8 7. 20 days

XI

2. (i) $(a+b-c-d)(a-b+c-d)$, (ii) $(x+y-z)(x-y+z+1)$.

3. $\dfrac{3x}{a}-1+\dfrac{a}{3x}$. 4. $x=y=z=1$ 5. $x^2-5xy+7y^2$

6. 480 at 16 a shilling, 90 at 18 7. 1

XII

2. 0 3. (i) $(x-b)(x+b-2a)$, (ii) $(x+a)(x+b+c)$.

4. $3x-1$ 5. 20 6. 10 7. $13\sqrt{3}$

XIII

3. 0 4. 0 5. 30. 6. 1 7. $46\sqrt[3]{2}$.

XIV.

3. 47 4. $a+b$ 5. $x=\frac{1}{2}(2a+b+c)$, $y=\frac{1}{2}(a+2b+c)$, $z=\frac{1}{2}(a+b+2c)$ 6. 5 days

7. $(x^2+5ax+5a^2)^2-a^4$

XV.

1. 4 3. $\dfrac{2x+3}{x^2+x+1}$. 4. $2x-3b$. 5. $\dfrac{1}{n}$. 6. 4.

7. 54 gallons

XVI

1. x^2+2x+3 2. 1 4. $x=2\frac{1}{2}, y=1\frac{1}{2}$

5. $(xy+ab)(ay^2+b^2x)$ 6. $-a^2-b^2-c^2+2ab+2ac+2bc$.

8. In the 1st, the wine is $\frac{1}{3}$ of the whole, in the second, $\frac{2}{3}$

XVII

1. x^2+x+1 2. $x=16, y=25$. 3. $n(n-1)$.

6. 72 7. $\dfrac{x^2-2x+3}{2x^2+5x-3}$.

XVIII

2. $\frac{5}{4}a$ 3. (i) $(7x-1)(2x-5)$, (ii) $2(a-c)(1-ac)$,
(iii) $2m^2n(m+n)$ 4. 1920 5. $a+b+c$.

7. $x=2, y=4, z=6$ 8. $\dfrac{c^2}{(b-d)^2}-\dfrac{a^2}{(b+d)^2}=1$

XIX

1. $\frac{4}{3}a$ 3. $ac-bc-b^2+a^2$. 4. $mq \cdot np$.

7. $\sqrt{6}-2$ 8. $a^3+b^3+c^3-3abc=0$

XX

3. $\dfrac{1}{abc}$ 4. $-(a^2+b^2+c^2+ab+ac+bc)$ 6. $x=c$,
or, $=c-\dfrac{a+b}{2}$ 7. $x=\dfrac{b+c}{2a}$, $y=\dfrac{a+c}{2b}$, $z=\dfrac{a+b}{2c}$.

8. 4 and 3 miles an hour, $3\frac{1}{2}$ miles

XXI.

5. $(a-b)(a+3b-2c)$ 6. x^2-x+3

7. $(ac'-a'c)^3=(ba'-b'a)^2(b'c-bc')$

XXII

4. 1020 yards 7. $x=b+c, y=c+a, z=a+b$

8. $a^3+b^3+c^3-3abc=0$

XXIII

2 $(7x-2)(4x-1)(3x-1)$ 6. $\dfrac{a^2+b^2+c^2}{bc+ca+ab}$.

8. $\dfrac{a^2}{p^2}+\dfrac{b^2}{q^2}=1$

XXIV

1. $x=a,\ y=b,\ z=c$ 2. 51, 81, 108.

6. $\dfrac{1}{a^2}+\dfrac{1}{b^2}=\dfrac{1}{(a-b)^2}$.

XXV

7. (i) $abc+2fgh-af^2-bg^2-ch^2=0$

(ii) $bc+ca+ab+2abc=1$

8. $\dfrac{1}{a}+\dfrac{1}{b}+\dfrac{1}{c}=\left(\dfrac{a'^2}{a}+\dfrac{b'^2}{b}+\dfrac{c'^2}{c}\right)\left(\dfrac{1}{a^2}+\dfrac{1}{b^2}+\dfrac{1}{c^2}\right)$.

EXERCISE 126. [Pages 510, 511]

1. ± 7 2. $\pm\frac{1}{2}$ 3. ± 2 4. ± 9

5. ± 2 6. $\pm\dfrac{\sqrt{3}}{2}$. 7. $\pm\dfrac{a}{2}\left(\dfrac{a^2-4}{a^2-1}\right)^{\frac{1}{2}}$. 8. $\pm\sqrt{mab}$

9. $\pm\dfrac{2}{b(4a-b^2)^{\frac{1}{2}}}$ 10. $\pm\dfrac{2a}{\sqrt{5}}$. 11. $\pm\sqrt{5}$ 12. $\pm\sqrt{pr}$

13. $\pm n\left(a-\dfrac{n^2}{4}\right)^{\frac{1}{2}}$. 14. $\pm\frac{1}{2}$

EXERCISE 127. [Page 514]

1. $-1, -12$ 2. $15, -14$ 3. $a, 3a$ 4. $b, 2a-b$.

5. $\dfrac{c}{a}, \dfrac{c}{b}$. 6. $\dfrac{3a}{4}, -\dfrac{8a}{3}$. 7. $a+\dfrac{3b}{5},\ a+\dfrac{7b}{2}$.

8. $\dfrac{6a-b}{5}, \dfrac{2a+5b}{7}$. 9. $\frac{6}{5}(a+b), -\frac{5}{4}(a+b)$ 10. $29\ -10$.

11. $1, \dfrac{2b}{a-b}$. 12. $a, -b$ 13. $\dfrac{a}{2}, \dfrac{3a}{4}$. 14. $4, 8$

15. $0, \dfrac{2ab-ac-bc}{a+b-2c}$. 16. $a, \dfrac{a}{5}$. 17. $2, -\frac{9}{5}$.

18. $2, -\frac{13}{3}$ 19. $5, -\frac{13}{4}$ 20. $4, \dfrac{-14}{5}$.

EXERCISE 128. [Pages 515—517]

3. $\frac{3}{4}, 7\frac{1}{4}$ **4.** $3\frac{3}{5}, 2\frac{2}{5}$ **5.** $2\frac{1}{3}, 2\frac{1}{4}$ **6.** $6\frac{1}{2}, -1\frac{2}{3}$
7. $1\frac{1}{3}, -2\frac{3}{5}$ **8.** 4, 05 **9.** $2 \pm \frac{1}{5}\sqrt{3}$ **11.** 9 8
12. $\frac{3}{5}, \frac{4}{7}$ **13.** $\frac{2}{3}, \frac{3}{10}$ **14.** $29, -10$ **15.** $10, -29$
17. $2, -3$ **19.** $\frac{4}{3}, 0$ **20.** $10, -\frac{2}{5}$ **21.** $24, \frac{42}{5}$
22. $\frac{1}{2}, \frac{57}{14}$ **23.** 3 **24.** $6, \frac{40}{13}$ **25.** $1, -\frac{40}{47}$ **26.** $\frac{-11 \pm \sqrt{13}}{6}a$

EXERCISE 129. [Page 517]

1. $3, 2\frac{2}{3}$ **2.** $-4, -5$ **3.** $\frac{4}{3}, -\frac{5}{2}$ **4.** $\frac{5}{3}, -$[illegible]$/3$
5. $2\frac{1}{2}, -\frac{3}{4}$ **6.** $5, \frac{5}{3}$ **7.** $-1\ \frac{5}{4}$

EXERCISE 130. [Page 520]

1. $\frac{3}{2}, -6$ **2.** $1\frac{2}{5}, -1\frac{1}{3}$ **3.** $\frac{5}{13}, -8$ **4.** $\frac{3}{2}, -34$
5. $9\frac{15}{17}, -11$ **6.** $\frac{a}{2}, \frac{3}{c}$ **7.** $ab, -\frac{a}{3}$.

EXERCISE 131. [Page 525]

1. 1, 2, 3 **2.** $1, \frac{1}{2}(3 \pm \sqrt{17})$ **3.** $1, -\frac{1}{2}, -3$
4. $-1, -2 \pm \sqrt{10}$ **5.** $1, \frac{1}{2}(3 \pm \sqrt{17})$ **6.** $\frac{1}{2}(1 \pm \sqrt{-3}), 2 \pm \sqrt{3}$
7. $1 \pm \sqrt{-3}, \frac{1}{2}(3 \pm \sqrt{-7})$ **8.** $-2 \pm \sqrt{6}, -2 \pm \sqrt{-6}$ **9.** $1, -8, \frac{1}{2}(-7 \pm \sqrt{-71})$ **10.** $-1 \pm \sqrt{5}, -1 \pm 2\sqrt{2}$ **11.** $1 \pm \sqrt{2}, 1 \pm \sqrt{5}$
12. $\frac{1}{2}(3 \pm \sqrt{5}), \frac{1}{2}(3 \pm \sqrt{-11})$ **13.** $1, 1 \pm \sqrt{2}, \frac{1}{4}(-1 \pm \sqrt{17})$
14. $\pm 1, \pm \sqrt{-1}$ **15.** $\pm 1, \pm 6$ **16.** 2, 3 **17.** 2, 3 **18.** 0, 1, 2 **19.** $\pm 1, \frac{1}{2}(1 \pm \sqrt{-3}), \frac{1}{2}(-1 \pm \sqrt{-3})$ **20.** ± 2 **21.** $2, \frac{1}{2}, \frac{1}{4}(5 \pm \sqrt{201})$ **22.** $2, \frac{1}{4}, \frac{1}{8}(9 \pm \sqrt{-31})$ **23.** $1, 2, \frac{1}{2}(3 \pm \sqrt{-1})$
24. $4, -6, -1 \pm 4\sqrt{2}$ **25.** $2, -\frac{1}{2}, 5, -\frac{1}{5}$

EXERCISE 132. [Pages 527—529]

1. Real but irrational **2.** Imaginary
3. Rational and unequal **4.** Real, rational and equal

5. Real but irrational   6. Imaginary

7. Imaginary   8. Real, irrational and unequal

9. Real, irrational and unequal   10. 8   11. ± 12

EXERCISE 133. [Pages 534—536]

1. $x^2-4x+3=0$ 2. $x^2+2x-35=0$

3. $3x^2-10x+3=0$ 4. (i) $x^2-6x+4=0$,

(ii) $x^2-4ax+4a^2-b=0$ 5. (i) sum$=5$, product$=6$,

(ii) sum$=-9$, product$=-13$,

(iii) sum$=\frac{20}{3}$, product$=-5$,

(iv) sum$=\frac{[illegible]}{5}$, product$=-\frac{3}{5}$,

(v) sum$=-\frac{1}{5}$, product$=\frac{1}{15}$

6. (ii) $x^2-p^2x+2q(p^2-2q)=0$,

(iii) $q^3x^2-p^2qx+2(p^2-2q)=0$,

(iv) $qx^2+p(q+1)x+(q+1)^2=0$

10. (i) $91x^2+8x+3=0$,

(ii) $cx^2+bx+a=0$ 13. $a=12$, $b=31$, $c=181$

14. $k=1$ 15. $a=k=2$

EXERCISE 134. [Pages 545—548]

1. 16, £5   2. 18   3. 3 inches   4. A's capital=£5, B's capital=£120   5. 5 miles per hour   6. 12, 5, $\frac{17}{\sqrt{2}}, \frac{7}{\sqrt{2}}$.

7. 5, 3   8. A, 120, B, 80   9. 7, 2

10. Rs 90   11. Small wheel 4 feet, large wheel 13 feet

12. 4 pence   13. 56   14. 20 and 30 miles per hour

15. £60, or, £40   16. 12, 16, 18   17. 26 and 38 feet

18. 25, 13, 6   19. 40 and 45 miles per hour   20. 256 square yards   21. 14, 10, 2   22. 6400   23. A, 10 miles per hour, B, 12 miles per hour   24. $\frac{(a-b)^4}{a^3}$.

25. The sides were 30 yds and 19 yds, and the height 4 yds

26. 100 shares at £15 each **27.** 15, 12, 10, 7
29. 625 **30.** 324 square feet

EXERCISE 135. [Pages 557, 558]

8. $\left.\begin{array}{l}x=8\\y=6\end{array}\right\}$; $\left.\begin{array}{l}x=6\\y=8\end{array}\right\}$. **9.** $\left.\begin{array}{l}x=4\\y=3\end{array}\right\}$, $\left.\begin{array}{l}x=-3\\y=-4\end{array}\right\}$.

10. $\left.\begin{array}{l}x=5\\y=7\end{array}\right\}$; $\left.\begin{array}{l}x=6\\y=6\end{array}\right\}$. **11.** $x=-2$, or, 6

12. -2, 8 **14** $x=8, x=-4, y=9, y=-3$

15. (5, 0), (0, 5)

EXERCISE 136. [Pages 575, 576]

16. (i) 1, (ii) 4, (iii) -7, (iv) 2·5 **17.** (i) 4, (ii) 4, (iii) 21, (iv) 1·5

18. $\left.\begin{array}{l}x=4\\y=1\end{array}\right\}$ and $\left.\begin{array}{l}x=1\\y=4\end{array}\right\}$. **20.** $\left.\begin{array}{l}x=4\\y=-2\end{array}\right\}$ and $\left.\begin{array}{l}x=-2\\y=4\end{array}\right\}$. **21.** 1·3

22. $1, -\frac{2}{3}$ **23.** 1, 2·5 **24.** $1, -\frac{5}{7}$

25. (i) $\left.\begin{array}{l}x=1·2\\y=6\end{array}\right\}$ and $\left.\begin{array}{l}x=-1·2\\y=-6\end{array}\right\}$; (ii) $\left.\begin{array}{l}x=-5\\y=-1\end{array}\right\}$ and $\left.\begin{array}{l}x=-1\\y=-5\end{array}\right\}$, (iii) $\left.\begin{array}{l}x=0\\y=0\end{array}\right\}$ and $\left.\begin{array}{l}x=1\\y=2\end{array}\right\}$, (iv) $\left.\begin{array}{l}x=0\\y=0\end{array}\right\}$ and $\left.\begin{array}{l}x=5\\y=25\end{array}\right\}$.

EXERCISE 137. [Pages 578, 579]

1. (i) 16, 40, $2n-6$, (ii) 15, 39, $2n-7$, (iii) $\frac{-29}{3}, \frac{-101}{3}, \frac{37}{3}-2n$, (iv) $\frac{-19}{7}, \frac{-67}{7}, \frac{25-4n}{7}$; (v) 47, 119, $6n-19$

2. 29*th*, 46*th*, $(3n-10)$*th* **3.** 6 **4.** 98 **5.** $-48, -44, -40$, 20*th* term $=28$ **6.** 1*st* term $=13$, 18*th* term $=-38$ **7.** 1*st* term $=2$ com diff $=3$

8. $\frac{d(p-r)-c(q-r)}{p-q}$.

EXERCISE 138. [Page 581.]

1. 325 **2.** 900 **3.** 504 **4.** 88 **5.** $\frac{-15}{22}$.

6. $1\frac{1}{7}$ **8.** $52\frac{1}{2}$ **9.** 0 **10.** 25452 **11.** $\frac{1}{2}(n-1)$

12. $\frac{n}{a+b}\left\{na-\frac{n+1}{2}b\right\}$. **13.** 720 **14.** n

15. $n(a+b)^2-n(n-1)ab$ **16.** 899 **17.** 704

18. $\frac{n}{2}\{(x-2y)n+x\}$ **19.** 4080 **20.** $\frac{21n-5n^2}{2}$.

EXERCISE 139. [Page 584.]

1. 3 **2.** 9 **3.** 7 **4.** 13 or 7.

5. Last term 3 or -1, number of terms 10 or 12

6. 18 or 19 **7.** n^2 **8.** $1, \frac{5}{4}, \frac{3}{2}, \frac{7}{4}$ 2, &c., 1470

9. 1, 3, 5, 7, &c., n^2 **10.** 2 **11.** 4 or 10

EXERCISE 140. [Page 586.]

1. $6\frac{1}{2}$, 8, m, a^2+x^2 **2.** (i) $9\frac{1}{3}$, $10\frac{2}{3}$, (ii) $\frac{2}{3}$, $7\frac{1}{3}$

3. 207, 297, 387 **4.** $-2, -6, -10, -14$

5. $1, -1\frac{1}{2}$, &c., -39 **6.** 14

EXERCISE 141. [Page 590.]

1. $\frac{n}{2}(6n^2+3n-1)$ **2.** $\frac{n(n+1)(n+2)(3n+5)}{12}$.

3. $\frac{n}{3}(4n^2+6n-1)$ **4.** $n^2(2n^2-1)$ **5.** $\frac{n(n+1)(n+2)}{6}$.

6. $\frac{n(n+1)(2n+1)}{6}$. **7.** $\frac{n(n+1)(n+2)(n+3)}{4}$.

8. $\frac{n}{12}(9n^3+46n^2+51n-34)$

9. $-\frac{n}{2}$ (if n is even) and $\frac{n+1}{2}$ (if n is odd)

10. $\frac{-n(n+1)}{2}$ (if n is even) and $\frac{n(n+1)}{2}$ (if n is odd)

EXERCISE 142. [Pages 595—597]

1. $\frac{ma-nb}{a-b}(2n+1)$ **2.** 9, 13, 17, 21, 25

3. 13, 6 **4.** 70 **5.** $\frac{n(n+1)(n+2)}{6}$.

6. $\frac{n}{6}(2n^2+3n+7)$ **7.** $\frac{n}{6}(2n^2+9n+1)$

8. (i) $\frac{n}{3(2n+3)}$; (ii) $\frac{n}{a(a+nb)}$. **9.** 8, 12, 16, 20

10. 3, 5, 7 **11.** 1, 3, 5, 7 **12.** 3 5 7, 9, 11, 13

16. 16 **19.** $\frac{n(n+1)(n+2)}{6}$. **20.** $\frac{1}{3}(n-1)n(2n-1)$ yards.

21. 16 **22.** 5

EXERCISE 143. [Pages 599, 600]

1. 8748 **2.** $\frac{4}{9}$ **3.** 65536 **4.** -243 **5.** $\frac{8}{27}$;
$\pm\frac{2^{n-3}}{3^{n-8}}$, + or, − according as n is even or odd

6. $-\frac{448}{243}$ **7.** $\frac{1}{25}, \frac{1}{125}$ **8.** (i) 6, 12, 24, 48, ;
(ii) 27, 9, 3, 1, or, −27, 9, −3, 1, ,

(iii) $\frac{81}{2}, -27, 18, -12,$ **9.** $\left(\frac{c^{n-q}}{d^{n-p}}\right)^{\frac{1}{p-q}}$.

11. pth term $=\sqrt{mn}$ and qth term $=m\left(\frac{n}{m}\right)^{\frac{n}{2q}}$.

EXERCISE 144. [Page 601]

1. 265720 **2.** $60\frac{20}{27}$ **3.** -682 **4.** $\frac{181}{576}$ **5.** $\frac{2}{3}(1-2^{2r})$.

6. $\frac{1}{14}\cdot\frac{5^n \mp 2^n}{5^{n-2}}$, − or, + according as n is even or odd

EXERCISE 145. [Page 604]

1. 1 **2.** $\frac{2}{3}$ **3.** $3\frac{1}{8}$ **4.** $\frac{3}{5}$ **5.** $10\frac{1}{8}$ **6.** $\frac{13}{24}$.

7. $\frac{11}{10}$ **8.** $\frac{3\sqrt{3}}{2}$. **9.** $\frac{1}{2}(4+3\sqrt{2})$ **10.** $\frac{1}{11}$

EXERCISE 146. [Pages 606, 607]

1. $6, 12$ **2.** $\frac{3}{2}, 1, \frac{2}{3}$ **3.** $-1, \frac{3}{2}, -\frac{9}{4}, \frac{27}{8}$

4. $\frac{16}{3}, 8, 12, 18, 27$

EXERCISE 147. [Pages 610—612]

1. $\frac{1}{36}, 1\frac{8}{55}; \frac{358}{1665}, \frac{1}{7}$. **2.** $\frac{1+x}{(1-x)^2}$. **3.** $\frac{2x}{(1-2x)^2}$.

4. $\frac{(1+6x)3x}{(1-3x)^2}$. **5.** $\frac{a(1-a^n)}{(1-a)^2}-\frac{na^{n+1}}{1-a}$. **6.** $\frac{1-x}{(1+x)^2}$.

7. 1 **8.** $4-\frac{n+2}{2^{n-1}}$. **9.** $2^{n-1}(2n-1)$, $2^n(2n-3)+3$

10. $\frac{5^{n+1}-5-4n}{16\times 5^{n-1}}$. **11.** $\frac{40}{81}(10^n-1)-\frac{4n}{9}$.

12. $n-\frac{1}{9}\left(1-\frac{1}{10^n}\right)$. **13.** $2^{n+1}-2-n$

14. $2(2^n-1-4n)$ **15.** $\frac{1}{3}(4^n-1+15n)$

18. $2, 5, 8$, or, $26, 5, -16$ **19.** $4, 8, 16$

20. $\frac{4}{5}, 4, 20$ **24.** $n\,2^{n+2}-2^{n+1}+2$

30. $\frac{1}{(1-x)(1-ax)}$.

UNIVERSITY MATICULATION PAPERS

ALLAHABAD

1927

1 Resolve any two of the following into elementary factors

(1) a^4+4b^4, (2) $8a^4+2a^2-45$,

(3) $a^2(b-c)+b^2(c-a)+c^2(a-b)$

2 Solve any two of the following equations

(1) $\frac{3-2x}{1-2x}-\frac{2x-5}{2x-7}=1-\frac{4(x^2-1)}{7-16x+4x^2}$,

(2) $\frac{12}{x+y}+\frac{8}{x-y}=8$, $\frac{27}{x+y}-\frac{12}{x-y}=3$

(3) $\frac{2x+3}{x}+\frac{4x}{2x+3}=4\frac{1}{3}$

3 Solve graphically the equations

$3x=17-2y$, $3y=2x+6$

4 The expenses of a family are Rs 72 a month when rice is at 10 seers a rupee and Rs 75 when rice is at 8 seers a rupee, if the other expenses remain constant, find these, the quantity of rice consumed every month being supposed constant

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1928

1 Resolve into factors

(a) $x^2y^2-6xyz-72z^2$, (b) $1-2x+2x^3-x^2$,

(c) $x^3-y^3+z^3+3xyz$

2. (a) Simplify $\frac{a}{(a-b)(a-c)}+\frac{b}{(b-c)(b-a)}+\frac{c}{(c-a)(c-b)}$.

(b) Solve $\frac{3}{x}+\frac{8}{y}=3$, $\frac{15}{x}-\frac{4}{y}=4$.

3 The sum of a number consisting of two digits and of the number formed by interchanging the digits is 110, and the difference between the digits is 6 Find the numbers

4 The annual expenses of a hospital are partly constant and partly proportional to the number of patients The expenses were Rs 7,680 for 12 patients and Rs 8,640 for 16 Draw a graph to show the expenses for any number of patients, and find from it the cost of maintaining 15

In a rival establishment the expenses were Rs 7,500 for 5 and Rs 8,900 for 15 patients Find graphically for what number of patients the cost would be the same in the two institutions

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1929

1 Resolve into real elementary factors

(a) $6x^2-23xy+20y^2$, (b) $x^4-7x^2y^2+y^4$, (c) x^6-1

2 (a) Solve $x^2-17x+72=0$

Find the sum, difference and the product of the roots of the given equation

(b) Find the value of $\frac{1}{x-2a}+\frac{2}{x+b}+\frac{1}{b}$, when $x=\frac{3ab}{b-a}$

3 Find the H C F of $24x^4-2x^3-60x^2-32x$ and $18x^4-6x^3-39x^2-18x$ and the square root of $4x^4+12x^3-11x^2-30x+25$

4 (a) The table below shows the distances from Allahabad of certain stations, and the times of two trains, one up and one down Supposing each run to be made at a constant speed, show by a graph the distance of each train from Allahabad at any time

	Distance in miles		
5-30 A M arr	0	Allahabad	dep 3-30 A M
No stop ↑ dep arr	78	Fatehpur	arr ↓ 5-45 A M dep 6-0 A.M
2-30 A M dep	120	Cawnpore	arr 7-0 A M

At what point do they pass one another, and how far is each from Allahabad at 4 A M

Or, (*b*) The following table gives the population (in millions) of two countries *A* and *B* for the years specified

years	1861	1871	1881	1891	1901	1911	1921
A	3 1	3 4	3 7	4 0	4 47	4 7	5 0
B	5 8	5 4	5 2	4 7	4 45	4 2	4 0

Plot the graphs on the same diagram Estimate approximately the population when it was the same in each country and the year in which this happened

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1930

1 Resolve into factors

(*a*) x^4+11x^2-180, (*b*) $x^4+x^2y^2+y^4$, (*c*) $x^3+y^3-3xy+1$

2 (*a*) Simplify $\dfrac{a^2(b-c)}{(a+b)(a+c)}+\dfrac{b^2(c-a)}{(b+c)(b+a)}+\dfrac{c^2(a-b)}{(c+a)(c+b)}$,

(*b*) Solve $\dfrac{x+1}{y+1}=\dfrac{3}{4}$, $\dfrac{x-1}{y-1}=\dfrac{2}{3}$

3 (*a*) If $x+\dfrac{1}{x}=5$, find the value of $x^2+\dfrac{1}{x^2}$

(*b*) A colonel wishing to form his men into a solid square finds he has 55 men over If he increases the side of the square by 1, he has 40 men too few How many men are there in the regiment ?

4 (*a*) Draw with the same axes the graph of

(i) $y+x=5$, (ii) $x=2y-3$, (iii) $x=7$,

and find the co-ordinates of the vertices of the triangle formed by them, also show that $2x-y-2=0$ passes through the intersection of (i) and (ii)

Or, (*b*) The following table gives the average weight and chest measurement corresponding to different heights, *H* is the height *W*

the weight, and C the chest measurement in feet and inches, lbs, and inches respectively

H	W	C
5 ft 0 in	122	34
5 ft 3 in	131	35 5
5 ft 6 in	137 5	37
5 ft 9 in	156 5	39
6 ft 0 in	173	40 5

Represent these graphically and deduce the weights and chest measurements of the average men of 5 feet 4 inches and 5 feet 8 inches

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1931

1 (a) Find the L C M of

$$4x^3+16x^2-3x-45 \text{ and } 10x^3+63x^2+119x+60,$$

(b) Find the H C F of

$$27a^6-45a^4-16 \text{ and } 18a^6-45a^4-5a-14$$

2 (a) Solve the equation

$$\frac{x-3\,5}{2x+5}=\frac{3x-1\,5}{2x-1},$$

(b) Simplify

$$\frac{(a+b)^2-ab}{(b-c)(c-a)}+\frac{(b+c)^2-bc}{(c-a)(a-b)}+\frac{(c+a)^2-ca}{(a-b)(b-c)}$$

3 (a) What number must be added to

$x^4+4x^3+10x^2+12x+3$ to make it a perfect square?

(b) A says to B, "I am twice as old as you were when I was as old as you are" The sum of their present ages is 63 Find their ages

4 (a) 0° Centigrade=32° Fahrenheit 100°C=212°F. Draw a graph showing the relation between the Centigrade and Fahrenheit scales, and find the Centigrade reading corresponding to 73°F

Or, (b) Construct the graphs of the equations

(i) $4x+6y=24$ and (ii) $2x+3y=6$

Find graphically the co-ordinates of the points of intersection of $4x-3y=6$ with (i) and (ii).

1932

1. (*a*) Solve $7x+\frac{3}{x}=35\frac{3}{5}$

(*b*) Simplify $\left(x+\frac{a-x}{1+ax}\right)\times\frac{x}{a}-\left\{1-\frac{x(a-x)}{1+ax}\right\}$.

2 Resolve into factors. (i) x^6-64b^6;

(ii) $x^2-1-2a-a^2$; (iii) $(a+2b)a^3-(b-2a)b^3$.

3 (*a*) A man distributed Rs 100 equally among his friends; if there had been five more friends each would have received one rupee less How many friends had he?

(*b*) If $x+\frac{1}{x}=5$, find the value of $x^3+\frac{1}{x^3}$.

4 Using the same axes and unit, draw the graphs of: (i) $y+x=0$, (ii) $5y=3x$, (iii) $y=3x+12$ Find the co-ordinates of the vertices of the triangle formed by the straight lines (i), (ii) and (iii)

BOMBAY

School Leaving Examination,

1928

1 (*a*) Find graphically the value of "q" which will make the two expressions $2q+3$ and $\frac{21-2q}{3}$ equal (unit=·4 inch)

(*b*) Draw a graph of $\frac{x^3}{5}$, plotting at least seven points.

2 (*a*) Resolve into factors

(i) x^4+64y^4; (ii) $(a+2b-c)^3-(a+b)^3-(b-c)^3$.

(*b*) Solve $\frac{1}{x}-\frac{2}{z}=-2$; $4x+5z=60xz$.

3. (*a*) If $p=x-y$, $q=y+z$ and $r=z-x$, express $r^2-p^2-2pq-q^2$ in terms of x, y and z

(*b*) The H C F of two quadratic expressions is $5x-4$ and their L. C M is $(15x^2-32x+16)(2x-5)$ Find the two expressions

(*c*) Solve $\frac{y+4}{3}-\left(\frac{3-5y}{11}+\frac{1}{2}\right)=y+\frac{1}{2}$.

4. (a) If $a+b=c$, prove that

$$\frac{1}{b^2+c^2-a^2}+\frac{1}{c^2+a^2-b^2}-\frac{1}{c^2-a^2-b^2}=0.$$

(b) Extract the square root of

$$x^4+\frac{1}{x^4}+4\left(x+\frac{1}{x}\right)\left(x-\frac{1}{x}\right)+2$$

5 A father says to his son, "You are now thrice as old as your mother was when you were born I am now thrice as old as your mother was ten years after your birth Ten years hence, I shall be twice as old as you were ten years ago" Find the present ages of the three.

6. (a) Solve $\frac{5x-9}{x-2}-\frac{4x+23}{x+6}=\frac{6x+49}{x+8}+\frac{21-5x}{x-4}$.

(b) Prove that $2xy$ (x^2+y^2) cannot be a ratio of greater inequality.

7 (a) If $(2ap+3bq)(2cp-3dq)=(2ap-3bq)(2cp+3dq)$, prove that a $c=b$ d

(b) Find five numbers in continued proportion such that the product of the 1st and the 5th is 144 and the sum of the 2nd and the 4th is 30

8. (a) If $(x+y)\propto(x-y)$, prove that $xy\propto(x+y)(x-y)$

(b) The total expenditure of a boarding establishment is partly constant and partly varies as the number of inmates and is met by equal contribution from the inmates With the fall in the number of inmates from 10 to 8, the individual contribution rises from Rs. 36 to Rs 40 What will be the total expenditure if the number of inmates rises to 15 ?

School Leaving Examination,

1929

1 (a) Find graphically the value of "y" that will make the expression $\frac{3y-16}{4}$ equal to 5

(b) Draw a graph of $\frac{2x^2}{4}$ (Plot at least 7 points)

2 (a) Find the square root of $x^3(x-6)+17x^2-8(3x-2)$.

(b) If $p=x+\frac{1}{x}$ and $q=x-\frac{1}{x}$, show that $p^4+q^4-2p^2q^2=16$

3. (a) Solve the equation $\frac{y+5}{6}-\left(\frac{14-y}{2}-\frac{1}{4}\right)=\frac{2y-7}{12}$.

(b) If $2x-\frac{2}{x}=3$, prove that $8\left(x^3-\frac{1}{x^3}\right)=63$

4 (a) Solve the equation $\frac{6}{y}-\frac{5}{x}=\frac{5}{y}-13=\frac{2}{x}-9$

(b) Simplify $\frac{x^3-8y^3}{x(x+2y)+4y^2}-\frac{8y^3+x^3}{x^2-2y(x-2y)}$

5 (a) Solve the equation $\frac{4y-11}{y-3}-\frac{3y+19}{y+6}=\frac{5y-24}{y-5}-\frac{4y+17}{y+4}$.

(b) Resolve into factors $a^4b-31a^2b^3+9b^5$

6 (a) Solve the equation $(x+4)(2x-3)=6$.

(b) If $x+y+z=0$, prove that $(y+z)(y-z)+x(x+2y)=0$

7 (a) If $\frac{x+r-p}{y+s-q}=\frac{p-r}{q-s}$, show that $\frac{y}{x}=\frac{s-q}{r-p}$.

(b) If the sum of two numbers is 45 and the mean proportional between them is 18, find them

8 (a) If $p=3q$ and $ap=bq$, prove that a varies as b

(b) The expenses of a hostel are partly constant and partly vary as the number of inmates. The expenses were Rs 1,200 when the number of inmates was 40, and Rs 800 when their number was 20 Find graphically or otherwise the number of inmates when the expenses were Rs 900

1930

1 (a) Simplify $\frac{x^2-2x-8}{x^3+8}\div\frac{x^2-7x+12}{x^4+4x^2+16}\times\frac{x^2+9-6x}{x^2+4+2x}$

(b) If $\frac{1}{x}-\frac{1}{y}$ varies inversely as $x-y$, prove that $x^2+y^2 \propto xy$

2 (a) Find the factors of $x^2-4x+\frac{15}{4}$.

(b) The weight of a sphere varies directly as the cube of its radius and as the density of the material of which it is made The radii of two spheres are as 16 : 7 and the densities of their materials as 2 : 3 If the weight of the first is 256 lbs, find the weight of the second.

3 (a) Solve $\frac{8}{x+2y}+\frac{3}{2x-y}=3$, $\frac{12}{x+2y}-\frac{6}{2x-y}=1$

(b) Solve the equation $\frac{2x-3}{3}=\frac{3x-5}{4}$ graphically

4 (a) Resolve into factors $xy^2-\frac{x^3}{27}+y^6+1$.

(b) If $p=3+\frac{1}{p}$, prove that $p^4=119-\frac{1}{p^4}$.

5. (a) Find the square root of $\left(x+\frac{1}{x}\right)^2-5\left(x-\frac{1}{x}\right)+\frac{9}{4}$.

(b) If $\frac{by+cz}{b^2+c^2}=\frac{cz+ax}{c^2+a^2}=\frac{ax+by}{a^2+b^2}$, prove that $\frac{x}{a}=\frac{y}{b}=\frac{z}{c}$.

6. A father says to his son, "Six years before your birth I was twice as old as your mother Ten years ago your mother was twice as old as you then were Three years hence I shall be twice as old as you will be." Find the present ages of the three

7. (a) Solve $\frac{6x-23}{x-4}-\frac{3x+16}{x+5}=\frac{5x-9}{x-2}-\frac{2x-5}{x-3}$.

(b) If $b+c$ be the mean proportional between $a+b$ and $c+a$, prove that $\frac{b+c}{c+a}=\frac{c-a}{a-b}$.

8 (a) Simplify $\frac{x+m^2}{(m-n)(m-p)}\times\frac{x+n^2}{(n-m)(n-p)}\times\frac{x+p^2}{(p-m)(p-n)}$

(b) Draw the graph of $\frac{2x^2}{5}$, plotting at least ten points

(Unit= 5 inch.)

1931

1 (a) Factorise $(3x^2-2x)^2-25$

(b) Solve $\frac{3x-4}{x-2}+\frac{4x+4}{2x+1}=\frac{2x-1}{2x-3}+\frac{4x+10}{x+2}$

2. (a) Resolve into factors $x^4-16x^2y^2+36y^4$

(b) If $\frac{x^2-yz}{a}=\frac{y^2-zx}{b}=\frac{z^2-xy}{c}$, find out two fractions, each equal to any of the given ratios, and having as their denominators $ax+by+cz$ and $a+b+c$ respectively Hence prove that either

$$(x+y+z)(a+b+c)=ax+by+cz, \quad \text{or, } x=y=z.$$

3. (a) Simplify $\frac{p^3+64q^3}{p^2+20pq+64q^2}\times\frac{p^2+12pq-64q^2}{p^3-64q^3}\div\frac{p^2-4pq+16q^2}{p^2+4pq+16q^2}$.

(b) If a, b, c are in continued proportion, prove that

$$a+b \cdot b+c=a^2(b-c) \quad b^2(a-b).$$

4. (a) Simplify $\frac{1}{a^2+6a+8}+\frac{1}{a^2+5a+6}-\frac{1}{a^2+7a+12}$.

(b) The volume of a pyramid varies as the area of its base when its altitude is constant, and varies as its altitude when the area of the base is constant When the area of the base of a pyramid is 16 sq ft and its cubical contents are 32 cub ft, its height is 6 ft Find the area of the base of another pyramid whose height is 20 ft and cubical contents, 120 cub ft.

5. (a) Extract the square root of $\left(x^2+\frac{1}{x^2}\right)^2-10\left(x^2-\frac{1}{x^2}\right)+21$

(b) Find graphically the value of x which will make $\frac{2x+1}{3}$ equal to $\frac{3x+4}{5}$ (State the units)

6. (a) If $p-\frac{1}{p}=2$, find the numerical value of $p^4+\frac{1}{p^4}$.

(b) Draw the graph of $y=x^2$ plotting at least 9 points (State the units you choose.)

7. (1) Solve $\frac{3}{x}-\frac{5}{y}=\frac{1}{2}$, $\frac{16}{y}-\frac{5}{x}=3$.

(2) Fill up the gaps in the following statements, using the word "directly" or "inversely" as the case may be and express each statement thus completed in algebraical symbols

(a) If the total amount of money to be spent is the same, the quantity of sugar purchased varies   as the price of sugar per cwt

(b) The distance travelled in a certain train by a railway train moving uniformly varies   as the speed of the train

8 The mother was twice as old as the son 18 years ago Thirty-two years ago the age of the father was equal to the sum of the ages of the mother and the son The father is 6 years older than the mother Find the present ages of the three

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1932

1. (a) Find the factors of $81x^4+47+\frac{16}{x^4}$

(b) If $ax=by=cz$, prove that

$$\frac{a^2+b^2+c^2}{x^2y^2+y^2z^2+z^2x^2}=\frac{ab+bc+ca}{xyz(x+y+z)}$$

2 (a) Factorise $8x^3+18x^2y-27xy^2-27y^3$

(b) Solve $\frac{5x-4}{x-1}-\frac{3x+7}{x+2}=\frac{6x-29}{x-5}+\frac{4x-7}{2-x}$

3 (a) Solve $\frac{4}{x+2}-\frac{1}{x+3}=\frac{4}{2x+1}$

(b) If $x^2-2x-1=0$, prove that $x(x^3-4x-4)=1$.

4. (a) Solve $\frac{3}{4x}-\frac{9}{8y}+\frac{3}{4}=0$, $\frac{3}{4y}-\frac{9}{8x}=\frac{7}{16}$

(b) If x, y, z are in the continued proportion, prove that

$$x+y \quad y+z=x^2(y-z) \quad y^2(x-y).$$

5. (a) The velocity of a body at the end of the 2nd, 3rd and 4th second is 16 ft, 22 ft, and 28 ft per second respectively Draw a graph to illustrate this and find from the graph the number of seconds at the end of which the velocity is 46 ft per second

(b) What expression of the first degree in x should be added to $9x^4-42x^3+103x^2-100x+80$ to make it a perfect square ?

6 (a) Simplify by clearing brackets

$$2-\{3x-(2x+5[x+3]+7)+2x+9\}-(2x-5)$$

(b) Draw the graph of $8y=x^3$, plotting at least 7 points.

(Use 8″ as your unit of length)

7 (a) Simplify

$$\left(\frac{x^3-64y^3}{15x^2-xy-2y^2}\times\frac{33x^2+8xy-y^2}{7x^2+28xy+112y^2}\right)-\frac{11x^2-45xy+4y^2}{5x^2+3xy-2y^2}.$$

(b) If $2x-3y \propto y+5x$, prove that

$$\frac{1}{3x^2}+\frac{1}{4y^2}\propto\frac{1}{2x^2}-\frac{1}{3y^2}$$

8 A piece of work can be done by a certain number of men in a certain number of days If the number of men is increased by 25, the work is done in 5 days less, but if the number of men is decreased by 50, it will take 20 days more to finish the work. Find the original number of men engaged to do it and the number of days taken by them to do it

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1933

1. (a) Factorise $\frac{9}{x^2}+4x^2+3$

(b) If p, q, r are unequal quantities in continued proportion, show that

$$\frac{p^3-q^3}{q^3-r^3}=\frac{p(p-q)}{r(q-r)}.$$

2. (a) Find the factors of $x^2-\frac{13}{6}x+1$

(*b*) If $a \propto b$, prove that $\frac{a^3+b^3}{a-b} \propto ab$.

3 (*a*) Solve the following equation

$$\frac{4x-15}{x-4}+\frac{5x-11}{2-x}=\frac{2x-1}{x-1}-\frac{3x-16}{x-5}.$$

(*b*) If $bcx=cay=abz$, prove that

$$\frac{ax+by}{a^2+b^2}=\frac{by+cz}{b^2+c^2}=\frac{cz+ax}{c^2+a^2}.$$

4 (*a*) Solve $\frac{7}{y}-\frac{2}{x}=29$, $\frac{3}{4x}-\frac{5}{4y}+4=0$.

(*b*) If $x^2=3x-4$ prove that $2x^3-11x^2+23x=20$

5 (*a*) Simplify $\frac{ab}{(a-c)(b-c)}+\frac{bc}{(b-a)(c-a)}+\frac{ca}{(c-b)(a-b)}$

(*b*) Find *graphically* the value of x which will make

$$\frac{3x-7}{4}=\frac{2x-5}{3},$$

and read from the graph the common value of these expressions for that value of x

6 (*a*) Prove that

$$z^3(x-y)^3-y^3(x-z)^3+x^3(y-z)^3=3xyz(x-y)(y-z)(z-x)$$

(*b*) Solve $\frac{2}{21(x-19)}+\frac{1}{3x-11}=\frac{2}{21(x+2)}$

7 A person spends a certain fixed sum of money in bying copies of a book at a certain price He finds that if the price were reduced by $16\frac{2}{3}$ per cent he would have bought 24 copies more and if the price were increased by 1 rupee per copy, he would have bought 30 copies less Find the fixed sum of money he spends

8. (*a*) Resolve into factors $9x^2(3x+1)-16y^2(4y+1)$

(*b*) Draw the graph of $5y=x^3$ taking $5''$ as a unit of length, and plotting at least the seven points whose abscissæ are 0, ± 1, ± 2, and ± 3

CALCUTTA

1925

Compulsory Paper

1. (1) Resolve into factors x^2-3x+2 and a^3-b^3.

(2) Simplify $$\frac{\frac{a^2}{x-a}+\frac{b^2}{x-b}+\frac{c^2}{x-c}+a+b+c}{\frac{a}{x-a}+\frac{b}{x-b}+\frac{c}{x-c}}.$$

2. (1) Find the H C.F. of $2x^2+9x+4$ and $2x^2-3x-2$.

(2) Find the L.C.M. of x^2-x-6 and x^3-4x+3.

3. *Either*, Solve: (1) $\frac{x+5}{6}-\frac{x+1}{9}=\frac{x+3}{4}$;

(2) $2x+3y=3$, $5x-2y=4$.

Or, (3) The sum of the digits of a number less than 100 is 6, if the digits be reversed the resulting number will be less by 18 than the original number, find the number

Additional Paper

1. (1) Solve $10x^2-69x-45=0$.

(2) *Either*, Find the common difference of an A.P. of which the 1st term is 1 and the 10th term, 10

Or, (3) Find the common ratio of a G.P. of which the 1st term is 2 and the 10th term, 1

2. *Either*, (1) Find the square root of

$$x^4+2x^3+\frac{x^2}{2}-\frac{x}{2}+\frac{1}{16}.$$

Or, (2) Simplify $\left\{\frac{(9^{n+\frac{1}{4}})\sqrt{(3.3^n)}}{\sqrt{3^{\ n}}}\right\}^{\frac{1}{n}}$.

3. Draw the graph of $y^2=4x$ and prove that there is no part of the graph on the negative side of the axis of y.

1926

Compulsory Paper

1. *Either*, (1) Find the product of

$(x^2+x+1)(x^2-x+1)(x^4-x^2+1)$.

(2) If $x+\frac{1}{x}=p$, express $x^3+\frac{1}{x^3}$ in terms of p.

Or, (3) Resolve into factors: (i) $x^2-12x+20$; (ii) x^4-a^4.

(4) Show that $(a+b)(x+y)$ is a factor of $(ax+by)^3+(bx+ay)^3$.

2 *Either*, (1) Find the H C F. of x^2-x-2, x^3+1, $(x+1)^2$.

(2) If $\frac{x}{a}=\frac{y}{b}$, prove that $(x^2+y^2)(a^2+b^2)=(ax+by)^2$.

Or, (3) Find the L C M of $6x^2-x-1$, $3x^2+7x+2$ and $2x^2+3x-2$

(4) Prove that $(a^2+b^2)(c^2+d^2)=(ac+bd)^2-(ad-bc)^2$.

3. *Either*, Solve. (1) $\frac{1}{x-1}+\frac{2}{x-2}=\frac{3}{x-3}$,

(2) $4x-y=5$, $7x-4y=2$

Or, (3) A number consists of two digits whose sum is 7 If the digits are inverted the number is increased by 9 Find the number

Additional Paper

1. (1) Solve the equation $\frac{1}{x-a}+\frac{1}{x-b}+\frac{1}{x-c}=0$.

(2) The arithmetic mean between two numbers is 15 and their geometric mean is 9 Find the numbers

2. (1) Find the square root of $x^4-2ax^3+5a^2x^2-4a^3x+4a^4$.

Or, (2) Simplify $\frac{1}{1+x^{b-a}+x^{c-a}}+\frac{1}{x^{a-b}+1+x^{c-b}}+\frac{1}{x^{a-c}+x^{b-c}+1}$

3 Draw the graph of $x^2=4y$

1927

Compulsory Paper

1 *Either*, (1) Divide x^4+x^2+1 by x^2+x+1

(2) If $a+b=3$, show that $a^3+b^3+9ab=27$.

Or, (3) Resolve into factors: (i) $x^2-12x+20$, (ii) x^3-8

(4) If $x=a^2-bc$, $y=b^2-ca$, $z=c^2-ab$, prove that

$$ax+by+cz=(a+b+c)(x+y+z)$$

2 (1) Find the H C F of x^3+x^2-2 and x^3+2x^2-3.

(2) If $bc+ca+ab=0$, prove that

$$\frac{1}{a^2-bc}+\frac{1}{b^2-ca}+\frac{1}{c^2-ab}=0$$

3. *Either*, Solve the equations:

(1) $\frac{x-a}{b+c}+\frac{x-b}{c+a}+\frac{x-c}{a+b}=3$; (2) $\frac{2}{x}+\frac{2}{y}=2$, $\frac{1}{x}-\frac{1}{2y}=\frac{1}{3}$.

Or, (3) The perimeter of a rectangular courtyard is 60 ft If the length of the courtyard is increased by 3 ft. and the width be decreased by 3 ft the area is decreased by 21 sq ft Find the dimensions of the courtyard

Additional Paper

1. Solve the equation $\sqrt{x^2+9}+\sqrt{x^2-9}=4+\sqrt{34}$.

2 Show that the sum of n terms of the series 4, 12, 20, 28,... is the square of an even number.

3 (1) Prove that $\sqrt{y+\sqrt{2xy-x^2}}+\sqrt{y-\sqrt{2xy-x^2}}=\sqrt{2x}$.

Or, (2) Find a value of x which will make $x^4+6x^3+11x^2+3x+31$ a perfect square.

4 Draw the graph of $y=(x+1)^2$.

1928

Compulsory Paper

1 *Either*, (1) Resolve into factors.

(i) $x^2-3x-28$; (ii) $81-x^4$.

(2) Prove that $(a^2+b^2+4ab)^2-(a^2+b^2)^2=8ab(a+b)^2$.

Or, (3) Divide $a^3(b-c)+b^3(c-a)+c^3(a-b)$ by $(a+b+c)$.

(4) If $a+b=1$, prove that $(a^2-b^2)^2=a^3+b^3-ab$

2 (1) Find the H C F of x^3+x^2+x+1 and x^3+3x^2+3x+1.

(2) If $x+y+z=2$ and $xy+yz+zx=1$, find the value of $(y+z)^2+(z+x)^2+(x+y)^2$.

3 *Either*, Solve the equations

(1) $\frac{x}{2}-2=\frac{x}{4}+\frac{x}{5}-1$, (2) $x+3y=7,\ 5x-y=3$;

Or, (3) Find a fraction which becomes $\frac{1}{2}$ on subtracting 1 from the numerator and adding 2 to the denominator, and reduces to $\frac{1}{3}$ on subtracting 7 from the numerator and 2 from the denominator.

Additional Paper

1. (1) Solve $\frac{x-6}{x+2}+\frac{x-10}{x+6}+2=0$.

(2) Prove that the arithmetic mean between two numbers is greater than their geometric mean.

2 (1) Find the square root of $x^4+4x+2+4x^{-2}+4x^{-3}+x^{-4}$.

Or, (2) If $x=y$, prove that $\left(\frac{x}{y}\right)^{\frac{x}{y}}=x^{\frac{x}{y}-1}$.

3. Draw the graph of $y^2+4x=0$.

1929

Compulsory Paper

1. (1) Find the factors of x^3-27 and $6-5a+a^2$.

(2) *Either*, Multiply $a^8-a^6+2a^4+a^2+1$ by a^4+a^2-1

Or, (3) Find the simplest value of

$$\frac{1}{(x-2)(x-3)}+\frac{1}{(x-3)(x-1)}+\frac{1}{(x-1)(x-2)}.$$

2. (1) Find the H C F of $3x^2-13x+12$ and $x^2+2x-15$

Either, (2) If $x=\frac{2ab}{a+b}$, find the simplest value of

$$\frac{x+a}{x-a}+\frac{x+b}{x-b}$$

Or, (3) Resolve $(a-b)^3+(b-c)^3+(c-a)^3$ into factors

3. *Either*, Solve the equations :

(1) $\frac{x+3}{4}-\frac{x+4}{5}=\frac{x+5}{6}-\frac{x+6}{7}$, (2) $x+y-3=0, 4x-5y+6=0$.

Or, (3) A motorist does a journey of 80 miles in 6 hours During the first part of the journey he travels at the rate of 10 miles and during the latter part at 18 miles an hour How far does he travel at each rate ?

Additional Paper

1 (1) If $(a+b+c+d)(a-b-c+d)=(a+b-c-d)(a-b+c-d)$, prove that $a \quad b=c \quad d$

Or, (2) If $p=a^z$, $q=a^y$, and $(p^yq^z)^x=a^2$, prove that $xyz=1$

2 *Either*, (1) Find the square root of

$$\frac{x^4}{4}+4x^2+\frac{ax^2}{3}+\frac{a^2}{9}-2x^3-\frac{4ax}{3}.$$

Or, Solve (2) $\frac{x+1}{x-1}-\frac{x-1}{x+1}=\frac{3}{2}$; (3) $\sqrt{x+2}+\sqrt{x-3}=5$

3 *Either*, (1) Find, without assuming any formula, the sum of the first n natural numbers.

(2) The second term of an A P is 6, and the fourth term is 14 Find the tenth term

Or, (3) Establish the formula for the sum of any number of quantities in G P

(4) Exhibit 0 $\dot{9}\dot{0}$ in the form of an infinite Geometrical Series, and hence find its value as a vulgar fraction

4 Draw the graph of $y=x^2$ between the limits $x=3$ and $x=-3$, and thence find the value of $\sqrt{5}$ to the first decimal place

1930

Compulsory Paper

1 (1) Factorise. $6-a-12a^2$ and x^3-3x+2.

(2) *Either*, Find the simplest value of

$$1.79\times1.79+2.42\times1.79+1.21\times1.21.$$

Or, (3) Divide $a^6+\dfrac{b^6}{27}$ by $a^2+ab+\dfrac{b^2}{3}$.

2 (1) Prove that $\dfrac{(a-b)^2}{(b-c)(c-a)}+\dfrac{(b-c)^2}{(c-a)(a-b)}+\dfrac{(c-a)^2}{(a-b)(b-c)}=3$.

(2) *Either*, Simplify $\dfrac{2}{x^2-1}+\dfrac{2}{x^2+x-2}+\dfrac{2}{x^2+3x+2}$.

Or, (3) If $a:b=c:d=e:f$, prove that

$$\frac{a}{b}=\left(\frac{a^2+c^2+e^2}{b^2+d^2+f^2}\right)^{\frac{1}{2}}.$$

3. *Either*, Solve

(1) $\dfrac{1}{x}-\dfrac{1}{x+1}=\dfrac{1}{x+2}-\dfrac{1}{x+3}$, (2) $a(x+y)=b(x-y)=2ab$.

Or, (3) If $x=3$ and $y=6$, how would you express the numbers 36 and 63 in algebraic symbols?

(4) A monarch who came to the throne at the age of 30 reigned for $\frac{4}{7}$ of his life. How long did he reign?

4 The plan of an orchard can be drawn by joining in order the points $A(3, 4)$, $B(5, -1)$ $C(-2, -4)$ and $D(-6, -2)$. Draw it on squared paper, taking five small divisions of your paper as unit. An artificial fountain is known to be situated at the intersection of AC and BD. Find the co-ordinates of the position of the fountain.

Additional Paper

1. (1) If m and n be positive integers, prove that $a^m\times a^n=a^{m+n}$.

Either, (2) If $x=2+2^{\frac{2}{3}}+2^{\frac{1}{3}}$, prove that $x^3-6x^2+6x-2=0$.

Or, (3) Show that $(x-1)(x-3)(x-5)(x-7)+16$ is a perfect square.

2. *Either*, Solve

(1) $x=\cfrac{1}{2-\cfrac{1}{2-\cfrac{1}{2-x}}}$; (2) $x^{\frac{2}{3}}+x^{\frac{1}{3}}-2=0$.

Or, (3) A man who went out between 4 and 5 P.M. and returned between 5 and 6 P.M. found that the hands of his watch had exactly changed places. When did he go out.

3 *Either*, (1) Find the sum of n terms of a series in A P

(2) A man undertakes to pay off a debt of Rs 65 by monthly instalments, he pays Rs 2 in the first month and continually increases the instalment in every subsequent month by Re 1. In what time will the debt be cleared up?

Or, (3) Insert three geometric means between 2 and 162

Prove that $a^{\frac{1}{2}} a^{\frac{1}{4}} a^{\frac{1}{8}}$ to infinity$=a$

(4) Find the sum of

$$(a-x)+(a^2-x^2)+(a^3-x^3)+ \ldots +(a^n-x^n).$$

4 In the same diagram draw the graphs of $2x+1$ and x^2 From your graphs read, as accurately as you can, the value or values of x which will make $x^2=2x+1$.

1931

Compulsory Paper

1. *Either*, (i) Divide $6x^3+x^2-5x-2$ by $2x+1$.

(ii) Find the L C M of $3x^2-10x+8$ and $2x^2-3x-2$.

Or, (iii) Resolve into factors: (1) $4x^2-4x-3$, (2) a^3-8b^3.

(iv) If $x+\dfrac{1}{x}=3$, find the value of $x^2+\dfrac{1}{x^2}$

2 *Either*, (i) Simplify $\dfrac{b^2c^2}{(a-b)(a-c)}+\dfrac{c^2a^2}{(b-c)(b-a)}+\dfrac{a^2b^2}{(c-a)(c-b)}$.

Or, (ii) If $\dfrac{b+c}{a}=\dfrac{c+a}{b}=\dfrac{a+b}{c}$, prove that *either*

$$a+b+c=0 \text{ or, } a=b=c.$$

3. *Either*, Solve the equations:

(i) $\dfrac{3}{x+1}+\dfrac{4}{x+2}=\dfrac{7}{x+3}$; (ii) $6y-x=1$, $\dfrac{x+y}{x-y}=\dfrac{3}{2}$

Or, (iii) The denominator of a fraction exceeds the numerator by 3, and if the numerator be increased by 7, the fraction is increased by unity. Find the fraction

4 Draw the graphs of $7x-2y=14$ and $x+2y=2$, and hence find the co-ordinates of their point of intersection.

Additional Paper

1 *Either*, (i) Prove that $(ab)^n=a^nb^n$, when n is a positive integer.

(ii) Find the simplest value of

$$\left(\frac{a^l}{b^m}\right)^n \left(\frac{b^n}{c^l}\right)^m \left(\frac{c^m}{a^n}\right)^l$$

Or, Solve:

(iii) $\dfrac{2x+1}{x-1}=\dfrac{x+8}{x+4}$; (iv) $\dfrac{x}{3}+\dfrac{3}{x}=4\frac{1}{4}$; (v) $x^2+\dfrac{36}{x^2}=13$

2 (i) Find the sum of $a+ar+ar^2+ar^3+\ldots$ to n terms.

Either, (ii) Exhibit $0\cdot\dot{7}$ as an infinite Geometrical series, and thence find its simplest value as a vulgar fraction.

Or, (iii) In the following groups of terms enclosed within brackets, find the value of the nth group and the sum of the first n groups

$$(1)+(1+3)+(1+3+3^2)+(1+3+3^2+3^3)+.$$

3 *Either*, (i) Join successively the points (2, 0), (4, 3), (2, 5), (0, 2), and (2, 0), and calculate the area of the quadrilateral, so formed.

[Take each of the smallest equal lengths on the graph paper as the unit of length, and each of the smallest squares as the unit of area]

Or, (ii) Draw the graphs of $y^2+x=0$ and $y+x=0$, and find the co-ordinates of their points of intersection from the diagram

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1932

Compulsory Paper

1. *Either*, (i) Find the H C.F of x^3-3x^2+x-3 and x^4+6x^2+5.

(ii) Solve $\dfrac{x+y}{xy}=5$, $\dfrac{x-y}{xy}=9$

Or, (iii) Resolve into factors

$$a^2(b+c)+b^2(c+a)+c^2(a+b)+3abc$$

(iv) The present age of a father is twice that of his son. Eight years hence their ages would be as 7 : 4. Find the son's present age.

2 Draw the graphs of $3x-2y=6$ and $2x+3y=0$ and measure their angle of intersection

Additional Paper

1 *Either*, (i) Solve $(17x-8)(x-2)=555$.

(ii) Simplify $(x^a)^{b-c}\,(x^b)^{c-a}.(x^c)^{a-b}$

Or, (iii) Extract the square root of

$$x^4+6x^3+11x^2+8x+7+\frac{2}{x}+\frac{1}{x^2}.$$

(iv) Solve $(\sqrt{3})^{2x+4}=216$.

2 *Either*, (i) Find the sum of n terms of an arithmetical progression of which the first term is a and the last term l

(ii) If a, b, c are respectively the pth, qth, and rth terms of an A.P, prove that

$$a(q-r)+b(r-p)+c(p-q)=0$$

Or, (iii) Find the sum of n terms of a geometrical progression of which the first term is a and the common ratio r.

(iv) If of three consecutive terms of a G P the middle term is 6 and the first and third terms are together equal to 15, find the series

3 Trace the graph of $y=x^2$ and $x=y^2$ with tabulation of at least six points on each graph Mention the co-ordinates of the points common to both.

1933

Compulsory Paper

1 *Either*, (i) Simplify

$$\frac{a-2x}{a+2x}-\frac{a+2x}{a-2x}+\frac{8ax}{a^2+4x^2}$$

(ii) Show that

$$-x^3-y^3-z^3+(x+y+z)^3=3(x+y)(y+z)(z+x).$$

Or, (iii) Divide $a^3+b^3-c^3+3abc$ by $a+b-c$

(iv) Solve the equation

$$0\cdot5x+\frac{0\cdot02x+0\cdot07}{0\cdot03}-\frac{x+2}{9}=9\cdot5$$

2 *Either*, (i) Find the H.C F. of x^3-3x-2 and $2x^3-5x^2+1$

(ii) Find the L C.M. of x^2-1, x^2+3x+2, and x^2+x-2

Or, Resolve into factors:

(iii) $m^4+m^2n^2+n^4$,

(iv) $a^2(b+c)+b^2(c+a)+c^2(a+b)+2abc$.

3 With the same axes of co-ordinates draw the graphs of (i) $3x-2y=0$, (ii) $y-3=0$, and (iii) $2x-y=1$

Additional Paper

1 *Either*, (i) Solve $3x^2-10x+3=0$

(ii) The area of a rectangular plot of land fenced all round is 2000 sq yds and the total length of fencing is 180 yds Obtain a quadratic equation to determine the length of the plot.

Or, (iii) Multiply $x^{\frac{1}{2}}+x^{-\frac{1}{2}}+1$ by $x^{\frac{1}{4}}+x^{-\frac{1}{4}}-1$.

(iv) Find the square root of

$$x^4-4x^3y+18x^2y^2-28xy^3+49y^4.$$

2. *Either*, (i) Find the sum of n terms of a G.P., given the first term and the common ratio.

(ii) Sum to infinity

$$\frac{1}{3}+\frac{1}{7}+\frac{1}{3^2}+\frac{1}{7^2}+\frac{1}{3^3}+\frac{1}{7^3}+\dots .$$

Or, (iii) Find the sum of n terms of an A.P., given the first term and the common difference.

(iv) Sum to n terms $1\times2+2\times3+3\times4+4\times5+\dots$

3. With the same axes of co-ordinates draw the graphs of (i) $x^2=y-2$, and (ii) $y=3x$, and find by measurement the co-ordinates of the points of intersection

DACCA

1927

Compulsory Paper

1. *Either*, (*a*) Find the product of x^2+y^2, $x+y$ and $x-y$.

(*b*) Divide $x^3+y^3-1+3xy$ by $x+y-1$.

Or, (*c*) Find the H.C.F. of

$2x^3-7x^2-46x-21$ and $2x^4+11x^3-13x^2+99x-45$

(*d*) Resolve into factors: (i) x^2-x-6; (ii) x^4+4.

2. *Either*, (*a*) If $\left(a+\frac{1}{a}\right)^2=3$, prove that $a^3+\frac{1}{a^3}=0$.

(*b*) Find the value of $a+b+c$, when $a^2+b^2+c^2=9$ and $bc+ca+ab=8$.

Or, (*c*) If $a+b+c=0$, prove that $a^2-bc=b^2-ca=c^2-ab$.

(*d*) If $\frac{a}{b}=\frac{c}{d}$, show that $\frac{a^2+b^2}{a^2-b^2}=\frac{ac+bd}{ac-bd}$

3. *Either*, (*a*) Solve $\frac{x+2}{x-2}+\frac{x-6}{x+6}=2$.

(*b*) A market woman bought a certain number of eggs at two a penny and as many at three a penny and sold them at the rate of five for two pence, losing $4d$ by the bargain. What number of eggs did she buy ?

Or, (*c*) Draw the graph of $3y-2x=4$ and from it find the solution of $2x+4=0$

Additional Paper

1 *Either*, (*a*) Factorise $x^2(b-c)+b^2(c-x)+c^2(x-b)$

(*b*) Solve $4x^2+25x-351=0$

Or, (*c*) If H and L represent the H C F and L C M. respectively of two expressions A and B, show that $H\times L=A\times B$

(*d*) The L C M of two expressions of the second degree is x^3-7x+6 and their H C F is $x-1$ Find the expressions

2 *Either*, (*a*) If $\frac{a}{y+z}=\frac{b}{z+x}=\frac{c}{x+y}$, prove that

$$\frac{a(b-c)}{y^2-z^2}=\frac{b(c-a)}{z^2-x^2}=\frac{c(a-b)}{x^2-y^2}$$

(*b*) What number must be taken from each of the numbers 9, 11, 15 and 19 to give the four results in proportion ?

Or, (*c*) Show, without assuming any formula, that the sum of the first n natural odd numbers is n^2.

(*d*) The first term of an infinite geometric series is 1, and any term is equal to the sum of the succeeding terms Find the series

3 Draw the graphs of $x^2+y^2+x-2=0$ and hence determine the roots of the equation $x^2+x-2=0$

1928

Compulsory Paper

1 (*a*) Divide $x^3+2x^2+cx+18$ by $x+3$, and find for what value of c there will be no remainder

Or, (*b*) Given $a+2b+3c=0$, find the numerical value of

$$\frac{2c}{a+c}-\frac{a}{b+c}$$

(*c*) Resolve into factors (i) $x^2-2x-15$, (ii) a^2-2a-b^2+2b

2 Solve (i) $\frac{1}{x-1}+\frac{2}{x-2}=\frac{3}{x-3}$, (ii) $3x+4y=27$, $5x-3y=16$

Or, (iii) Find the fraction which becomes $\frac{1}{2}$ when 1 is added to its denominator and $\frac{1}{4}$ when 2 is subtracted from its numerator.

3. (a) If $x \,.\, y=y \;\; z$, find the simplest value of

$$\frac{xyz(x+y+z)^3}{(xy+yz+zx)^3}$$

(b) If $\dfrac{x}{y+z}=a$, $\dfrac{y}{z+x}=b$, $\dfrac{z}{x+y}=c$, obtain an equation connecting a, b, c and independent of x, y, z.

Or, (c) Draw the graph of the expression $\dfrac{2x+7}{3}$ and read off its value when $x=4$. Find from the graph the value of x for which the given expression is 0.

Additional Paper

1. (a) Solve $6x^2-2x-21=0$

(b) Find the value of $\sqrt[bc]{\dfrac{x^b}{x^c}} \times \sqrt[ca]{\dfrac{x^c}{x^a}} \times \sqrt[ab]{\dfrac{x^a}{x^b}}$.

Or, (c) Find the square root of $x^2-6x+5+\dfrac{12}{x}+\dfrac{4}{x^2}$.

(d) Simplify $\dfrac{\sqrt{2}(2+\sqrt{3})}{\sqrt{3}(\sqrt{3}+1)}-\dfrac{\sqrt{2}(2-\sqrt{3})}{\sqrt{3}(\sqrt{3}-1)}$.

2. (a) Find the sum of the first n natural numbers without assuming any formula.

(b) Insert 10 arithmetical means between 2 and 57.

Or, (c) Find a formula for the sum of a series in G.P.

(d) The 5th term of a G P is 48 and the 12th term 6144. Find the first term and the common ratio

3. (a) Draw the graphs of $x^2+y^2=25$ and $3x+4y=25$, and find where they meet

Or, (b) A man and his family consume 10 seers of rice in a week. If his wages were raised 5% and the price of rice raised $2\frac{1}{2}$%, he would gain 8 *as.* a week But if his wages were lowered $11\frac{1}{4}$% he would lose $9\frac{3}{4}$ *as.* a week Find the price of a seer of rice. [Supposing his other expenses remain the same]

1929

Compulsory Paper

1. (a) If $x=a+b$, $y=b+c$, $z=c+a$, prove that

$$x^2+y^2+z^2-xy-yz-zx=a^2+b^2+c^2-ab-bc-ca$$

Or, (b) If $a+b+c=0$, prove that $a^2-bc=b^2-ca=c^2-ab$.

(c) Find the L C M of x^2-3x+2, x^2-4x+3 and x^2-5x+6.

Or, (d) Find the factors of (i) $x^2+4x-21$; (ii) x^3-27

2. Solve any two of the following equations

(i) $\frac{3x+2}{x-1}-\frac{2x-4}{x+2}=5$, (ii) $5x-3y=1$ and $5y-3x=9$,

(iii) $\frac{1}{x-2}-\frac{1}{x-4}=\frac{1}{x-6}-\frac{1}{x-8}$

3. (*a*) Explain clearly what you understand by the graph of an equation

Draw the graph of the equation $y-2x+4=0$ and find from it the solution of the equation $2x-4=0$

Or, (*b*) The manager of a boarding house having already 50 boarders, finds that an addition of 10 more boarders increases the gross monthly expenditure by Rs 20, but diminishes the average cost per head by Re 1 What did the monthly expenses originally amount to ?

Additional Paper

1 *Either*, (*a*) Factorise x^3-3x+2. (*b*) Solve $x^2-26x=407$.

Or, (*c*) The difference between a proper fraction and its reciprocal is $\frac{9}{20}$ Find the fraction

2 *Either*, (*a*) Find a meaning for a^{-n}.

(*b*) Simplify $\frac{1}{1+x^{n-m}+x^{p-m}}+\frac{1}{1+x^{m-n}+x^{p-n}}+\frac{1}{1+x^{m-p}+x^{n-p}}$

Or, (*c*) Sum to to n terms 3, 6, 9, 12, without assuming any formula

(*d*) The sum of 3 terms of a G P is 63, and the difference between the first and third terms is 45. Find the terms

3 Draw the graphs of $y=x^2$ and $2y-5x+3=0$, and hence obtain the solution of the equation $2x^2-5x+3=0$

1930

Compulsory Paper

1. (*a*) (i) Divide $x^5-y^5+\frac{y^{10}}{x^5}$ by $x-y+\frac{y^2}{x}$

Or, (ii) Find the L C M of x^4-2x+1 and x^3+2x^2-1

(*b*) (i) If $\left(x+\frac{1}{x}\right)^2=3$, prove that $x^3+\frac{1}{x^3}=0$

Or, (ii) Simplify $\frac{a+x}{(a-b)(a-c)}+\frac{b+x}{(b-c)(b-a)}+\frac{c+x}{(c-a)(c-b)}$

2. (*a*) Resolve into factors :

(i) x^4+2x^2+9 ; (ii) $a(b^2-c^2)+b(c^2-a^2)+c(a^2-b^2)$

(*b*) (i) If $x=b+c-a$, $y=c+a-b$, $z=a+b-c$, prove that

$$x^3+y^3+z^3-3xyz=4(a^3+b^3+c^3-3abc)$$

Or. (ii) If $x \;\; a=y \;\; b=z \cdot c$, prove that

$$\frac{x^3}{a^2}+\frac{y^3}{b^2}+\frac{z^3}{c^2}=\frac{(x+y+z)^3}{(a+b+c)^2}.$$

3 (*a*) Solve the equations ·

(i) $\frac{x+2}{x-2}+\frac{x-6}{x+3}=2$, (ii) $\frac{5}{x}+3y=8$, $\frac{4}{x}-10y=56$.

Or, (*b*) A man rode a certain distance at a uniform rate in $2\frac{1}{2}$ hours. If the distance had been a mile less and his rate per hour 2 miles more, he would have taken half an hour less Find his rate.

4. Draw the graph of the equation $\frac{x}{3}+\frac{y}{4}=1$, and measure its intercept between the two axes.

Additional Paper

1 *Either*, (*a*) Solve one of the following equations :

(i) $\sqrt{x+1}+\sqrt{x+8}=\sqrt{6x+1}$, (ii) $10x^2-69x+45=0$.

(*b*) Find for what value of x, $9x^4-12x^3+22x^2-13x+12$ will be a perfect square.

Or, (*c*) Resolve into factors one of the following expressions :

(i) $21x^2-80x-84$, (ii) $x^3-13x+12$

(*d*) Prove that for all integral values of m and n

$(a^m)^n=a^{mn}$, hence show that

$$\left(\frac{x^l}{x^m}\right)^{l+m}+\left(\frac{x^m}{x^n}\right)^{m+n}\times\left(\frac{x^n}{a^l}\right)^{n+l}=1.$$

2. Attempt any two of the following

(*a*) The first term of an A.P is 2, the 20th term is 59. Find the 32nd term

(*b*) Insert 9 G M between $\frac{81}{16}$ and $\frac{64}{729}$.

(*c*) a is the first term of a G.P., l is the nth term, and P is the product of first n terms Show that $P=(al)^{\frac{n}{2}}$

3 (*a*) Draw the graphs of $y=x^2$, and $x-y+6=0$. Hence find the solution of the equation $x^2-x-6=0$

Or, (*b*) A day labourer gets Re 1 for every day he works and loses 8 annas for every day's absence He takes rest for one day after every three day's work Draw a graph of his earning and determine from it how much he will get after 10 days

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1931

Compulsory Paper

1 (*a*) The product of two expressions is

$$\tfrac{1}{3}x^4+\tfrac{1}{36}x^3-\tfrac{1}{6}x^2+\tfrac{17}{72}x-\tfrac{1}{12},$$

and one of them is

$$\tfrac{1}{2}x^2-\tfrac{1}{3}x+\tfrac{1}{4},$$

find the other

(*b*) If $x=y+z$, show that $x^3-y^3-z^3=3xyz$.

Or, (*c*) Find the value of $a^2+b^2+c^2-bc-ca-ab$, when $a=x+y$, $b=x-y$ and $c=x+2y$

2 (*a*) Resolve into factors (i) $3(2x^2-1)-7x$, (ii) x^4+64.

(*b*) If $bc+ca+ab=0$, prove that $\dfrac{1}{a^2-bc}+\dfrac{1}{b^2-ca}+\dfrac{1}{c^2-ab}=0$.

Or, (*c*) If $\dfrac{a}{y+z}=\dfrac{b}{z+x}=\dfrac{c}{x+y}$, prove that

$$\frac{a(b-c)}{y^2-z^2}=\frac{b(c-b)}{z^2-x^2}=\frac{c(a-b)}{x^2-y^2}.$$

3. (*a*) Solve the equations

(i) $\dfrac{2}{2x-5}+\dfrac{1}{x-3}=\dfrac{6}{3x-1}$, (ii) $x+y=2xy$, $x-y=xy$.

Or, (*b*) A number consists of two digits the tens' digit being twice the units' If the digits are interchanged, the number is diminished by 18 Find the number

Additional Paper

1 (*a*) Find, to first four terms, the square root of a^2+x^2.

Or, (*b*) Assign a meaning, with reason, to $x^{-2\frac{1}{2}}$.

(*c*) Express ·001 as a negative power of 10

(*d*) Arrange according to the descending powers of x,

$$1+x+x^{-1}-2x^2-2x^{-2}.$$

(e) Solve the equation $4\times 2^{x-1}=8^x$.

2. (a) Find the number of terms of the series 17, 5, −7,......... whose sum is −78.

Or, (b) If a, b, c are in A.P., show that

$$(a+2b-c)(2b+c-a)(c+a-b)=4abc$$

(c) Show that the product of any two terms of a G.P. equidistant from the beginning and the end is constant.

Or, (d) A body moves in such a manner that it travels a distance of 100 yds. in the first minute, 60 yds in the second minute, 36 yds. in the third minute, and so on in geometric progression. Show that the total distance travelled, even if the body moves externally cannot be greater than 250 yds

3. (a) Solve the following equations

(i) $x^6-28x^3+27=0$, (ii) $\frac{x}{x+1}+\frac{x+1}{x}=\frac{25}{12}$.

Or, (b) Find graphically the maximum value of $6x-x^2-5$.

1932

Compulsory Paper

1. (a) Find the continued product of

$$1+x+x^2,\ 1-x+x^2, \text{ and } 1-x^2+x^4$$

Or, (b) Find the H.C.F of x^4-5x^2+4 and $x^5-11x+10$

(c) If $x=\frac{4ab}{a+b}$, prove that $\frac{x+2a}{x-2a}+\frac{x+2b}{x-2b}=2$.

2. (a) Resolve into factors

(i) $a^2b^2-a^2-b^2+1$, (ii) $(x+y+z)(xy+yz+zx)-xyz$.

(b) Eliminate t from the equations.

$$x=t+\frac{1}{t}, \text{ and } y^2=t^2+\frac{1}{t^2}$$

Or, (c) If $x : a=y : b=z : c$, then show that

$$\frac{x^3+y^3+z^3}{a^3+b^3+c^3}=\frac{xyz}{abc}$$

3. *Either* (a) Solve the equation $\frac{x}{2x-a}+\frac{x}{2x-b}=1$.

(b) Draw the graph of the equation $y=\frac{3-x}{4}$.

Or, (c) Find the fraction which reduces to $\frac{1}{2}$ when 1 is added to its denominator, and $\frac{1}{3}$ when 2 is subtracted from its numerator.

Additional Paper

1 (*a*) Assign a meaning with reason to $a^{\frac{p}{q}}$, where p and q are positive integers

(*b*) Multiply $x^{2^{n-1}}+a^{2^{n-1}}$ by $x^{2^{n-1}}-a^{2^{n-1}}$.

Or, (*b*) Extract the square root of

$$\frac{x^{-\frac{4}{5}}}{9}+x^{-\frac{2}{5}}\left(4+\frac{a^{\frac{1}{3}}}{3}\right)+\frac{a^{\frac{2}{3}}}{4}-\frac{4x^{-\frac{3}{5}}}{3}-2x^{-\frac{1}{5}}a^{\frac{1}{3}}.$$

2 (*a*) The first term of an A P is 9 and the last term is 96. If the sum be 1575, find the common difference

Or, (*b*) Find the sum of the squares of the first n natural numbers

(*c*) Find the sum of the first n terms of a G.P.

Or, (*d*) Exhibit $\cdot 0\dot{6}$ in the form of an infinite Geometrical series, and hence find its value as a vulgar fraction

3. (*a*) Solve the following equations

(i) $\frac{2x}{5}+\frac{5}{2x}=3\frac{1}{3}$; (ii) $6(x^4+1)=13x^2$

Or, (*b*) Draw the graph of x^2+2x+5 from $x=-5$ to $x=4$ Find from the graph the minimum value of the function and the value of x that gives the minimum value

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1933

Compulsory Paper

1. (*a*) Divide $a^3-b^3+c^3+3abc$ by $a-b+c$.

Or, (*b*) Find the L C M of $x^3-16x+24$ and $2x^3-5x^2+4$.

(*c*) Resolve into factors:

(i) x^4-16y^4; (ii) $a(b-c)x^2+b(c-a)x+c(a-b)$.

2 (*a*) Simplify

$$\frac{3a-b-c}{(a-b)(a-c)}+\frac{3b-c-a}{(b-c)(b-a)}+\frac{3c-a-b}{(c-a)(c-b)}.$$

Or, (*b*) If $a \quad b=b \,.\, c=c \quad d$, prove that

$$(b-c)^2+(c-a)^2+(d-b)^2=(a-d)^2.$$

(c) Draw the graph of

$$\frac{x}{3}+\frac{y}{4}=1,$$

and measure its intercept between the axes

3. (a) Solve the equations :

(i) $\frac{x+7}{x-9}=\left(\frac{x+5}{x+6}\right)^2$,

(ii) $\frac{3}{x}+\frac{2}{y}-\frac{3}{z}=0,\ \frac{5}{x}-\frac{6}{y}+\frac{2}{z}=0,\ 2x+3y+4z=6$

Or, (b) A boat goes up-stream 30 miles and down-stream 44 miles in 10 hours, it also goes up-stream 40 miles and down-stream 55 miles in 13 hours Find the rate of the stream and of the boat

Additional Paper

1 (a) Solve, without assuming any formula, the equation $x^2-x=1806$.

(b) Extract the square root of

$$\frac{x^2}{y^2}+\frac{y^2}{x^2}-\frac{x}{y}+\frac{y}{x}-1\frac{3}{4}.$$

Or, (c) Prove that

$$\sqrt[bc]{\frac{x^b}{x^c}}\times\sqrt[ca]{\frac{x^c}{x^a}}\times\sqrt[ab]{\frac{x^a}{x^b}}=1.$$

(d) Calculate

$$\frac{\sqrt{2}(2+\sqrt{3})}{\sqrt{3}(\sqrt{3}+1)}-\frac{\sqrt{2}(2-\sqrt{3})}{\sqrt{3}(\sqrt{3}-1)},$$

correct to 2 places of decimals.

2 (a) Show that the sum of n terms of an A P is equal to n times half the sum of the first term and the last term.

(b) Sum to n terms $1\times2+2\times3+3\times4+4\times5+$etc

Or, (c) If a be the first term of a G.P, l the last term, and P the product of the first n terms, show that $P=(al)^{\frac{n}{2}}$.

(d) Sum to n terms $1+2x+3x^2+4x^3+5x^4+$etc.

3 (a) Solve, by the graphical method, the following equations

$$y-2x=0,\ y^2-5x=0.$$

Or, (b) A boy buys a certain number of oranges at 3 for 2 pice and $\frac{1}{3}$ of that number at 2 for 1 pice At what uniform price must he sell them to get 20 per cent profit? If his profit be 5 *as.*, find the number bought.

MADRAS

1927

1. Factorise (i) x^8+81x^4+6561,

(ii) $a(b^3-c^3)+b(c^3-a^3)+c(a^3-b^3)$

2 (i) If $a+b+c+d=0$, prove that $a^3+b^3+c^3+d^3$ is equal to $3(a+b)(a+c)(a+d)$.

(ii) Determine the value of k so that the expression $x^4+5x^3-6x^2+kx+35$ may be exactly divisible by $x+5$

3. (i) Solve $\frac{1}{x}+\frac{3}{y}=2.5$, $\frac{2.5}{x}+\frac{4}{y}=4.5$;

(ii) Find the value of l to satisfy the relation

$$W=\frac{3}{4}al\left(1+\frac{l}{10}\right), \text{ given } W=5400 \text{ and } a=10,$$

(iii) In an examination 60 per cent of the boys and 70 per cent of the girls passed Of the total number that failed 64 per cent were boys What per cent of the candidates were boys ?

4 Draw the graph of $y=(3x-1)(x+3)$ between the values $x=-4$ and $x=2$ Hence determine the roots of the equation $x(3x+8)=5$ to the first decimal place.

1928

1. Factorise (i) $18x^2+53x-35$,

(ii) $(a^2-b^2)(b^3-c^3)+(c^2-b^2)(a^3-b^3)$

2. (i) If $\frac{x}{y}+\frac{y}{x}=a$, $\frac{y}{z}+\frac{z}{y}=b$, $\frac{z}{x}+\frac{x}{z}=c$, prove that

$$a^2+b^2+c^2-abc=4,$$

(ii) If the co-efficients of x^4 and of x in the product of $2x^3+3x^2+ax-10$ and $3x^3-ax^2-10x+4$ are equal to one another, find the value of a

3. (i) Solve $\frac{2x+3}{x-1}-\frac{2x+9}{x+4}=\frac{3x+7}{x+2}-\frac{3x+16}{x+5}$;

(ii) Solve $\frac{2}{x}+\frac{1}{3-x}=2$,

(iii) A merchant beginning business with a certain capital succeeded in doubling it, but afterwards lost Rs 1000 He employed

the remainder in a venture which brought him in a profit of 35 per cent, after which his capital was found to be 10 rupees more than his original capital. Find the amount of that capital.

4 Find *graphically* the maximum value of $6x-x^2-5$.

1929

1. Resolve into factors:

(i) $81x^8-7x^4y^4+y^8$, (ii) $a^4(b-c)+b^4(c-a)+c^4(a-b)$.

2 (i) If $x-\frac{1}{x}=1$, prove that $x^3-\frac{1}{x^3}=4$,

(ii) Divide $x^2+x^{-2}+2$ by $x^{\frac{2}{3}}+x^{-\frac{2}{3}}-1$

3. (a) Solve the equations:

(i) $\left(x-\frac{5}{2}\right)\left(\frac{1}{x}+\frac{3}{5}\right)+1=0$;

(ii) $3\cdot55x-55\cdot3y=55\cdot3x-3\cdot55y=5\cdot885$.

(b) A man bicycled from one town to another going the first half of the distance one and a half miles per hour slower than his usual rate, and the second half, two and a half miles per hour faster than his usual rate His average rate for the whole journey was $7\frac{1}{2}$ miles an hour. Find the usual rate of bicycling.

4 Solve graphically the equation $x^2+5x+3=0$, correct to the first decimal place

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1930

1. Resolve into factors. (i) $6x^2-xy-12y^2-4x-11y-2$;

(ii) $(a^2-b^2)(b^3-c^3)-(b^2-c^2)(a^3-b^3)$

2 (i) Simplify $\frac{11}{8(x-3)}-\frac{7}{2(x-1)^3}-\frac{11}{4(x-1)^2}-\frac{11}{8(x-1)}$;

(ii) Show that, if $a(b-c)x^2+b(c-a)xy+c(a-b)y^2$ is a perfect square, then $b(a+c)=2ac$.

3. (i) Solve the equations:

(a) $\frac{4x-11}{x-3}-\frac{2x-17}{x-9}=\frac{3x-22}{x-7}-\frac{x-10}{x-9}$,

(b) $\frac{1}{x}+\frac{1}{y}+\frac{1}{z}=13$,

$\frac{1}{y}-\frac{1}{z}=1$,

$\frac{1}{xy}-\frac{2}{z}=0$.

(ii) A walks a certain course and back again; B, starting at the same time and from the same place, walks at half the pace of A over five-eighths of the course and back again. A passes B half a mile from the starting-point. Find the length of the course.

4. Draw the graph of $y=x^3-3x$, using a large x unit. Hence solve, as accurately as you can, the equation $x^3-3x=4{\cdot}5$.

Check by calculation.

1931

1. (i) Given that $x+\dfrac{1}{x}=5$, find the value of $x^3+\dfrac{1}{x^3}$.

(ii) Find the values of l and m in order that

$x^4+lx^3+mx^2-12x+9$ may be a perfect square.

2. (i) Factorise $x^4-14x^2y^2+y^4$.

(ii) Simplify

$$\frac{(a+b)^3-c^3}{(a+b)^2-c^2}+\frac{(b+c)^3-a^3}{(b+c)^2-a^2}+\frac{(c+a)^3-b^3}{(c+a)^2-b^2}-2(a+b+c).$$

3. (i) Solve the equations

$$\frac{1}{x}+\frac{2}{y}=3,$$
$$\frac{2}{x}+\frac{3}{y}=4.$$

(ii) There are two chests of mixed tea: in one the green is mixed with the black in the ratio 2 : 3, in the other the ratio is 3 : 7. How many pounds must be taken from each chest so as to form a new mixture containing exactly 3 lbs. of green tea and 6 lbs. of black tea?

4. Draw the graphs of $y=3x^2$ and $y=2x+10$. Hence find the roots of the equation $3x^2-2x-10=0$. Verify by calculation.

PATNA

1928

1. (a) Divide $2a^2x^2-2(b-c)(3b-4c)y^2+abxy$ by $ax+2(b-c)y$.

Or, (b) If $\left(x+\dfrac{1}{x}\right)^2=3$, prove that $x^3+\dfrac{1}{x^3}=0$.

(c) Find the H.C.F. of $x^4-3x^3-2x^2+12x-8$ and x^3-7x+6.

(d) Find the L.C.M. of $8x^3+27$, $16x^4+36x^2+81$, and $6x^2-5x-6$.

2 (*a*) Simplify $\left(\dfrac{x^m}{x^n}\right)^{m+n-l} \times \left(\dfrac{x^n}{x^l}\right)^{n+l-m} \times \left(\dfrac{x^l}{x^m}\right)^{l+m-n}$

Or, (*b*) If $\dfrac{x}{a}=\dfrac{y}{b}$, show that $\dfrac{x^3}{a^2}+\dfrac{y^3}{b^2}=\dfrac{(x+y)^3}{(a+b)^2}$.

(*c*) Find the square root of

$$4a^4+9\left(a^2+\frac{1}{a^2}\right)+12a^2\left(a+\frac{1}{a}\right)+18.$$

Or, (*d*) Solve $x^2-23x-420=0$ without assuming any formula.

3 (*a*) Draw the graph of $3x-2y=1$, $2x-y=1$ and find from the graphs their point of intersection

(*b*) One of the digits of a number is greater by 5 than the other When the digits are inverted the number becomes $\frac{3}{8}$th of the original number Find the number

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1929

1 (*a*) Multiply $x^{\frac{1}{2}}+x^{\frac{1}{2}}y^{-\frac{1}{2}}+y^{\frac{1}{2}}$ by $x^{-\frac{1}{2}}-x^{-\frac{1}{2}}y^{\frac{1}{2}}+y^{-\frac{1}{2}}$.

Or, (*b*) Factorize the expression

$$x^4-2x^2a^2-2x^2b^2+a^4+b^4-2a^2b^2.$$

(*c*) Reduce to its lowest terms $\dfrac{x^4-x^3-x+1}{x^4-2x^3-x^2-2x+1}$.

Or, (*d*) Find the L.C.M of x^3-x^2-5x+2 and x^3+4x^2+x-6.

2. (*a*) Simplify $\dfrac{(x+a)^2}{(a-b)(a-c)}+\dfrac{(x+b)^2}{(b-c)(b-a)}+\dfrac{(x+c)^2}{(c-a)(c-b)}$.

Or, (*b*) If $ap=bq=cr$, show that $\dfrac{p^2}{qr}+\dfrac{q^2}{rp}+\dfrac{r^2}{pq}=\dfrac{bc}{a^2}+\dfrac{ca}{b^2}+\dfrac{ab}{c^2}$.

(*c*) Solve, without assuming any formula, the equation

$$2x^2-3x-629=0.$$

Or, (*d*) Extract the square root of $6x^{\frac{4}{3}}+9x^2-4-11x^{\frac{2}{3}}+4x^{-\frac{2}{3}}$.

3. (*a*) Draw the graph of each of the following

(i) $\dfrac{2x-3}{6}$, (ii) $2x-1$

Hence show how to find the solution of the equation

$$\frac{2x-3}{6}=2x-1$$

Or, (*b*) A man and a boy can do in 12 days a piece of work which could be done in 2 days by 7 men and 4 boys How long would it take one man or one boy to do it?

1930

1 (*a*) Factorize $(x^2+3x-6)(x^2+3x-2)-32$

Or, (*b*) If $x=3^{\frac{1}{3}}-3^{-\frac{1}{3}}$, prove that $3x^3+9x=8$

(*c*) Find the H C F of

$6x^4+7x^3+5x^2+2x$ and $4x^5-18x^4-8x^3-10x^2$.

Or, (*d*) Find the L C M. of

$x^2-7x+12$, $3x^2-6x-9$ and $2x^3-6x^2-8x$.

2 (*a*) Solve, by completing the square, the equation

$$24x^2-7x-6=0$$

Or, (*b*) If $(x+1)(x+2)(x+3)(x+4)+c$ is a perfect square, find c.

(*c*) Draw a graph of $2x+3$ from $x=-3$ to $x=+3$. What is the increase in $2x+3$ between $x=-1$ and $x=+2$?

3 A man s age is four times the sum of the ages of his three children, and in 8 years it will be twice the sum What is the man's age ?

Supplementary Paper

1. (*a*) If $x^3-2(p+2)x^2+px+4$ is exactly divisible by $x+2$, find the value of p

Or, (*b*) Factorize $bc(b-c)+ca(c-a)+ab(a-b)$.

(*c*) If $\frac{x}{b-c}=\frac{y}{c-a}=\frac{z}{a-b}$, find the value of

$$(b+c-a)x+(c+a-b)y+(a+b-c)z$$

Or, (*d*) If $a . b :: c : d :: e \cdot f$, show that each of these ratios is equal to $\sqrt[3]{a^3+c^3+e^3} . \sqrt[3]{b^3+d^3+f^3}$.

2 (*a*) Find the H C F. of

$3x^3-5x^2+5x-2$ and $2x^4-2x^3+3x^2+x+1$.

Or, (*b*) Find the L C M. of

x^2+x-2, x^2-x-6 and x^3-x^2+x-1

(*c*) Solve graphically the following equations :

$$x-3y=3x-10y=1.$$

Or, (*d*) A number of two digits is such that the sum of the digits is 9 If the digits are reversed, the number is less by 9 than before Find the number.

3 (*a*) Solve, by completing the equation $2x^2-x-210=0$.

Or, (*b*) Extract the square root of $9a-12a^{\frac{1}{2}}-2+4a^{-\frac{1}{2}}+a^{-1}$.

1931

1. *Either*, (*a*) Simplify

$$\frac{b-c}{a^2-(b-c)^2}+\frac{c-a}{b^2-(c-a)^2}+\frac{a-b}{c^2-(a-b)^2}.$$

Or. (*b*) Prove that

$$(a^2+b^2+c^2)^2=4(a^2c^2+b^2c^2+c^2a^2), \text{ if } a+b+c=0.$$

Either (*c*) Reduce to its lowest term the fraction,

$$\frac{7-10x-11x^2+6x^3}{14+x+4x^2-3x^3}.$$

Or. (*d*) Show that, if the four quantities, a b, c. d are proportional, then

$$(a+b+c+d)(a-b-c+d)=(a-b+c-d)(a+b-c-d)$$

2 (*a*) Solve, by completing the square, the equation

$$7x^2+13x=2$$

(*b*) Draw the graph of $y+3x+2=0$, for values of x from $x=0$ to $x=-4$ and by the aid of your graph, obtain the value of x, when $y=8$

3 *Either*,

(*a*) Find the square root of

$$x^{\frac{5}{3}}-4x^{\frac{4}{3}}+4x+2x^{\frac{2}{3}}-4x^{\frac{1}{3}}+x^{-\frac{1}{3}}.$$

Or, (*b*) Two men, 40 miles apart, walking in opposite directions, meet in $6\frac{2}{3}$ hours, but if one of them had doubled his pace, they would have met in $\frac{3}{4}$th of the time. Find their respective speeds

Supplementary Paper

1 *Either*, (*a*) Factorize $a^3(b-c)+b^3(c-a)+c^3(a-b)$

Or, (*b*) If $x=a^2-bc$, $y=b^2-ac$, $z=c^2,-ab$, show that

$$ax+by+cz=(a+b+c)(x+y+z)$$

Either, (*c*) Find the H.C F. of

$$2x^3+3x^2y-y^3 \text{ and } 4x^3+xy^2-y^3.$$

Or, (*d*) Simplify $\frac{1}{x^2-3x+2}+\frac{1}{x^2-4x+3}+\frac{1}{x^2-5x+6}$.

2. *Either*, (*a*) Solve, by completing the square, the equation

$$15x^2-28=x$$

Or, (*b*) Find a value of x so that $16x^{\frac{4}{3}}-24x+25x^{\frac{2}{3}}-20x^{\frac{1}{3}}+20$, may be a perfect square.

(*c*) Plot the graphs on the same axes of

(i) $y=3x+2$, (ii) $y+1=4x$,

from $x=0$ to $x=4$ and find from the graphs the value of x and y where they intersect

3. *Either*, (*a*) If $\frac{a}{b}=\frac{c}{d}=\frac{e}{f}$, show that

$$(a^2+c^2+e^2)(b^2+d^2+f^2)=(ab+cd+ef)^2.$$

Or, (*b*) A man and a boy can do in 15 days a piece of work which would be done in 2 days by 7 men and 9 boys How long would it take one man or one boy to do it ?

1932

1 *Either*, (*a*) Find the continued product of

$$x^2+x+1,\ x^2+x-1, \text{ and } x^4-2x^3+x^2+1$$

(*b*) Find the H C F of

$$10x^3+11x^2+9 \text{ and } 6x^3+5x^2+9.$$

Or, (*c*) Simplify

$$\left(\frac{x^m}{x^n}\right)^{m+n}\times\left(\frac{x^n}{x^l}\right)^{n+l}\times\left(\frac{x^l}{x^m}\right)^{l+m}.$$

(*d*) Find the L C M of

$$x^2-4ax+4a^2,\ x(x-y)-2a(2a-y) \text{ and } x^2-y^2+4ay-4a^2$$

2, *Either*, (*a*) Find the value of $x^2+y^2+z^2+2xy+2yz+2zx$, when $x=a+b-c$, $y=b+c-a$, $z=c+a-b$.

(*b*) If $\frac{a}{b}=\frac{c}{d}=\frac{e}{f}$, show that

$$\frac{2a^3-3c^3+4e^3}{2b^3-3d^3+4f^3}=\frac{a^2e}{b^2f}$$

Or, (*c*) Solve graphically the equations

$$3x+2y=5, \text{ and } 5x-2y=3.$$

(*d*) Find a so that

$4x^4+12x^3+25x^2+ax+16$ may be a perfect square.

3 *Either*, (*a*) Solve, without assuming any formula, the equation

$$\frac{3}{x-5}+\frac{2x}{x-3}=5.$$

Or, (*b*) Five years hence father's age will be 3 times the son's age and 5 years ago father was 7 times as old as his son. Find their present ages

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1933

1. (*a*) Resolve into factors

(i) $(x^2-y^2)(a^2-b^2)+4xyab$;

(ii) $xy-y^2+5y-3x-6$.

Or, (*b*) Find the H.C F of

$4x^3-12x-8$ and $6x^3-24x^2+30x-12$.

(*c*) Simplify $\frac{1}{a^2-bc}+\frac{1}{b^2-ca}+\frac{1}{c^2-ab}$,

when $ab+bc+ca=0$.

2 (*a*) Solve by completing the square, the equation

$5x^2-\frac{1}{3}x=3\frac{2}{3}-x$.

(*b*) Find a so that

$$\frac{4}{x}x^2-8\frac{x}{y}+\frac{4}{3}x+36y^{-2}-\frac{a}{y}+1.$$

may be a perfect square

Or, (*c*) Show that

$2(a^4+b^4+c^4)=(a^2+b^2+c^2)^2$, when $a+b+c=0$.

3 (*a*) Draw, with the same axes, the graphs of

(i) $y=4x$, (ii) $2x+y=18$; and find from the graphs the point where they intersect.

Or, (*b*) A man rows 30 miles down a river in 6 hours and returns in 10 hours Find the rate at which the man rows and also the rate at which the river flows.

PUNJAB

1925

1. Resolve into elementary factors.

(i) $49x^4-44x^2y^4+4y^8$, (ii) x^6-1

2 Solve the following equations

(i) $\frac{x+2}{3}+2=\frac{x+4}{5}+\frac{x+6}{7}$, (ii) $2x-15y=3x-24y=1$

3 (i) What value (not zero) must 'a' have if x^2+x-a and x^2-x-a have a common factor?

(ii) If $x+\frac{1}{x}=a$, find the value of $x^3+\frac{1}{x^3}$

4 Solve graphically the equations $4x+3y-12=0$, $2x-y-16=0$. Find the intercepts of the latter on the axes of x and y.

5. (i) If $\frac{a^2+c^2}{ab+cd}=\frac{ab+cd}{b^2+d^2}$, prove that $\frac{a}{b}=\frac{c}{d}$

(ii) Eliminate y from the following equations

$$y+\frac{1}{y}=m,\ y-\frac{1}{y}=n$$

Or, (iii) After walking at the rate of $3\frac{1}{2}$ miles per hour until the number of miles left of my journey was the same as the number of hours I had been walking, I quickened my pace to 4 miles per hour and accomplished the whole distance in 2 hrs 55 min What was the length of my journey?

1926

1 Find the factors of x^6-64 and x^4-7x^2+1.

2 (i) Find the H.C F of $8x^4-21x^3+1$ and $x^4-21x+1$

(ii) Extract the square root of $x^4+y^4+(x+y)^4$

3. Solve the equations (i) $\frac{3x}{4}+\frac{1-2x}{5}=2\frac{1}{5}-\frac{x-\frac{1}{4}}{3}$

(ii) $px+qy=r,\ qx-py=0$

4 Draw a graph of $x=1+y$ and $2x+4y=17$ in the same diagram Hence solve the equations

5 Show that if $x \quad a=y\,.\,b=z \quad c$, then

(i) $\frac{x^3+y^3+z^3}{a^3+b^3+c^3}=\frac{xyz}{abc}$, (ii) $\frac{x^3}{a^3}+\frac{y^3}{b^3}+\frac{z^3}{c^3}=3\frac{(x+y+z)^3}{(a+b+c)^3}$

1927

1 (i) Find the factors of $8x^3+1$ and x^4+2x^2+9

(ii) Find the H C F. of $8x^4+3x+10$ and $10x^4+3x^3+8$

2. (i) Extract the square root of $\left(x+\frac{1}{x}\right)^2-4\left(x-\frac{1}{x}\right)$

(ii) Find the value of $x^4+\frac{1}{x^4}$, when $x=3+\sqrt{8}$

3. (i) Solve $\frac{7x-1}{4}-\frac{1}{3}\left(2x-\frac{1-x}{2}\right)=6\frac{1}{3}$

(ii) Draw the graphs of $y=x$, and $y=2x+1$, and determine their point of intersection

4. (i) Show that if $x \quad a=y \quad b$, then $(a^2+b^2)(x^2+y^2)=(ax+by)^2$.

(ii) Eliminate z from $ax+by+cz=0$, and $\frac{a}{x}+\frac{b}{y}+\frac{c}{z}=0$

1928

1. (i) Prove that for all values of x, $x^3-a^3=(x-a)(x^2+ax+a^2)$.

(ii) Factorize x^8+14x^4+81.

(iii) The H C F and L C M of two integral expressions A and B, each of the 2nd degree, are $x+3$ and x^3-7x+6 Find A and B

2. (i) Prove that $(x+1)^4=x^4+4x^3+6x^2+4x+1$

(ii) Extract the square root of $x^4-10x^3+33x^2-40x+16$

(iii) Evaluate $\sqrt{x}-\frac{1}{\sqrt{x}}$, when $x=3+2\sqrt{2}$

3 (i) For what finite value of x will the expression

$$\frac{2(x-1)}{x+3}+\frac{3(x-2)}{x+1} \text{ equal to } 5?$$

(ii) Plot the graphs of $x+y=1$ and $2x+3y=6$, and verify that their point of intersection is $(-3, 4)$

4 (i) If $\frac{x}{a}=\frac{y}{b}=\frac{z}{c}$, show that $\left(\frac{ax+by+cz}{a^2+b^2+c^2}\right)^3=\frac{xyz}{abc}$.

(ii) Eliminate t from $x=\frac{a(1+t^2)}{1-t^2}$ and $y=\frac{2bt}{1-t^2}$

1929

1 Assuming that for all values of x

$$x^2-\alpha^2=(x+\alpha)(\beta x+\gamma), \text{ determine } \alpha, \beta, \gamma.$$

Deduce that $(a+b)^2=a^2+2ab+b^2$

If $\sqrt{18+6\sqrt{5}}=\sqrt{x}+\sqrt{y}$, find x and y

2 (i) Factorize $x^3-19x-30$

(ii) Determine the common factors of the expressions
$6x^3-11x^2-4x+4$ and $10x^3-19x^2-5x+6$

(iii) For what value of x will

$$x^4-12x^3+217x+320 \text{ be a perfect square?}$$

3 (a) Show that an equation of the first degree in x cannot have more than one root x and y are connected by the relation

$$pxy+qx+ry+s=0, \text{ where } p, q, r, s \text{ are real numbers}$$

Given y, show that x is unique and is, in general, different from y What is the condition that y may be the same for all values of x

4 (i) If $\frac{x}{a}=\frac{y}{b}=\frac{z}{c}$, show that

$$\left(\frac{a^2x^2+b^2y^2+c^2z^2}{a^3x+b^3y+c^3z}\right)^{\frac{3}{2}}=\sqrt{\frac{xyz}{abc}}.$$

(ii) Solve the equations $5x-3y=9$ and $3x+5y=19$

Verify the solution by graphs, and measure the angle between the lines represented by the equations.

5 (i) Prove that $(a^m)^n=a^{mn}$, where m and n are positive integers.

(ii) Eliminate y from $m=y^x$ and $n=x^y$.

(iii) Verify that $[(1+x)^2]^3=[(1+x)^3]^2$.

1930

1 (a) Write down *briefly* 54 3×54 3×54 3×1,000,000

(b) Find the value of $\sqrt[5]{32^4}$

(c) Multiply by the method of detatched co-efficients

$$4x^2-5+6x^3 \text{ by } 7x+x^3-3$$

2. (a) Solve the equations

$$\left.\begin{array}{l} a_1x+b_1y=c_1 \\ a_2x+b_2y=c_2 \end{array}\right\}$$

(b) Use your results to find the solution of

$$\left.\begin{array}{l} 2x-3y+6=0 \\ 4x-\ \ y-8=0 \end{array}\right\}$$

(c) And test the solution *graphically*

3 (a) Simplify $\frac{x^2-1}{x^2+x-2}\times\frac{x^3+8}{x^4+4x^2+16}-\frac{x^2+x}{x^3+2x^2+4x}$

(b) Simplify $\frac{1}{a(a-b)(a-c)}+$ two similar terms.

(c) Find the value of x in $9^x = \frac{9}{3^x}$

4. (a) Show algebraically that $10^n - 1$ is *always* divisible by 9.

Or, (b) Nine chairs and 5 tables cost Rs 90, while 5 chairs and 4 tables cost Rs. 61. Find the price of 6 chairs and 3 tables.

(c) Eliminate t from the equations

$$\left.\begin{aligned} v &= u + ft \\ s &= ut + \tfrac{1}{2}ft^2 \end{aligned}\right\}$$

1931

1 (a) Divide $2x^3+5x^2-mx+4$ by x^2+2x-1, and find the value of x for which the given divisor would be a factor of the given dividend.

(b) Extract the square root of $x^4+4x^3+10x^2+12x+9$.

2 (a) Supply the missing terms in the following identity.

$$(p+\quad)(p+\quad)(p+\quad)$$
$$\equiv \qquad +p^2(q+2r+3s)+p(\qquad)+$$

(b) Prove that

$$\frac{n(n-1)(n-2)(n-3)}{1.2.3.4}+\frac{n(n-1)(n-2)}{1.2.3} \equiv \frac{(n+1)n(n-1)(n-2)}{1.2.3.4}.$$

3 Solve the equations

(a) $\left.\begin{aligned} x+y&=25 \\ y+z&=27 \\ z+x&=32 \end{aligned}\right\}$ (b) $\sqrt{2x+3}+\sqrt{2x-1}=2.$

4. (a) Simplify by factors:

$$\frac{x^3-a^3}{x^3+b^3} \times \frac{x^2+ax+bx+ab}{x^4+a^2x^2+a^4} \div \frac{x^2-a^2}{x^3+a^3}.$$

(b) If $\frac{a}{x}=\frac{b}{y}=\frac{c}{z}$, prove that $\frac{x^3+y^3+z^3}{a^3+b^3+c^3}=\frac{xyz}{abc}$

Or, (c) Eliminate l, m, n from the equations:

$$\begin{aligned} mz+ny&=l \\ nx+lz&=m, \\ ly+mx&=n \end{aligned}$$

5. (a) The difference between the length and breadth of a rectangle is 14 ft, and its area is 275 sq ft.

(1) Find its semi-perimeter.

(2) Find its length and breadth.

(b) Find the values of A, B and C in

$$p^2-10p+13 \equiv A(p^2-5p+6)+B(p-1)(p-2)+C(p-1)(p-3).$$

1932

1 (a) $\dfrac{x-p}{q}+\dfrac{x-q}{p}=2$, find x.

(b) In the cyclic quadrilateral $ABCD$,

$\angle A=(2x+13)$ degrees
$\angle B=(2y-18)$ degrees
$\angle C=(y+31)$ degrees,
$\angle D=(3x-29)$ degrees

Find the values of x and y

2 (a) Simplify $(x+1)^5-(x-1)^5$

(b) Find the square root of $4x^4+8x^3+8x^2+4x+1$, *hence* find the square root of 48841

3 (a) $(x+5)$ is a factor of $2x^3+9x^2-8x-15$, find the other factor by decomposing the given expression, and if possible factorise that factor still further

(b) Simplify

$$\frac{a}{(a+b)^2-2ab}\times\frac{a^4-b^4}{(a+b)^3-3ab(a+b)}\div\frac{(a+b)^2-4ab}{(a+b)^2-3ab}$$

4 (a) $\sqrt{31+4\sqrt{21}}=\sqrt{x}+\sqrt{y}$, find x and y

(b) Prove that

$$\frac{y^{-1}}{x^{-1}+y^{-1}}+\frac{y^{-1}}{x^{-1}-y^{-1}}=\frac{2xy}{y^2-x^2}.$$

5 (a) Eliminate x from the equations

$$\left.\begin{aligned} ax+\frac{b}{x}&=m\\ ax-\frac{b}{x}&=n \end{aligned}\right\}$$

(b) If $3x^3+9x^2+7x+2\equiv A(x+1)^3+B(x+1)+C$, find the values of A, B and C.

Or, (c) Given that 1 cubic foot contains 6 25 gallons, draw a graph to convert cubic feet into gallons

Read off the number of gallons in 18 5 cubic feet

1933

1 (a) Resolve into factors x^6-729.

(b) If $x-\frac{1}{x}=c$, find the value of $x^3-\frac{1}{x^3}$.

2 (a) Solve the equation

$$\frac{1}{x-1}+\frac{2}{x-2}=\frac{3}{x-3}$$

(b) Find the square root of $10-2\sqrt{21}$

3. (a) For what value of a will the expression

$$4x^4-12x^3+25x^2-24x+a$$

become a perfect square?

(b) Find the H C F of

$$6x^4-13x^3+6x^2 \text{ and } 8x^4-36x^3+54x^2-27x.$$

4 (a) If $\frac{a}{b}=\frac{c}{d}=\frac{e}{f}$, prove that

$$\frac{a^2ce}{b^2df}=\sqrt{\frac{a^5c^4e^8}{b^5d^3f^8}}$$

(b) Eliminate t from

$$\frac{c}{t}+\frac{t}{c}=x,$$

$$\frac{c}{t}-\frac{t}{c}=y$$

5 (a) Solve the equations

$$2x+y=18$$

and $3y=33+x$

(b) Verify the result by means of a graph

ANSWERS TO UNIVERSITY MATRIC. PAPERS

All. 1927

1 (1) $(a^2+2ab+2b^2)(a^2-2ab+2b^2)$, (2) $(2a+3)(2a-3)(2a^2+5)$,
(3) $(a-b)(b-c)(a-c)$ 2 (1) $x=-\frac{5}{8}$; (2) $x=\frac{5}{2}, y=\frac{1}{2}$,
(3) $x=3$, or, $-\frac{2}{3}$ 3. $x=3, y=4$. 4 120 seers, Rs 60

All. 1928

1 (a) $(xy-12z)(xy+6z)$, (b) $(1+x)(1-x)(1-2x)$,
(c) $(x-y+z)(x^2+y^2+z^2-xy-yz+zx)$
2. (a) 0, (b) $x=3, y=4$. 3 82, 28 4 8400, 20

All. 1929

1 (a) $(3x-4y)(2x-5y)$, (b) $(x^2+3xy+y^2)(x^2-3xy+y^2)$,
(c) $(x-1)(x+1)(x^2-x+1)(x^2+x+1)$ 2 (a) 9, 8, 17, 1, 72,
(b) $\dfrac{1}{a}$ 3 $x(3x+2)$, $2x^2+3x-5$

4 (a) The two trains will meet at about 4-37 A.M at a distance of nearly 39 miles from Allahabad

Down train	60 miles		from Allahabad	} at 4 A M
Up "	18 5	" nearly	" "	}

(b) 4 25, 1899

All. 1930

1 (a) $(x-3)(x+3)(x^2+20)$, (b) $(x^2+xy+y^2)(x^2-xy+y^2)$,
(c) $(x+y+1)(x^2-xy+y^2-x-y+1)$ 2. (a) 0,
(b) $x=5, y=7$. 3 (a) 23, (b) 2264. 4 (a) $\frac{7}{3}, \frac{8}{3}$ 7, 5, 7, −2

All. 1931

1 (a) $(2x-3)(10x^3+63x^2+119x+60)$, (b) $3a^2-3a+2$
2 (a) $\frac{1}{2}$ or $-5\frac{1}{2}$, (b) 0
3 (a) 6, (b) 42 and 21 years respectively
4 (a) $22\frac{7}{9}$°C i e, 22 78°C, nearly, (b) (3, 2) and (2 $\frac{2}{3}$)

All. 1932

1. (a) 5 or $\frac{5}{31}$ (b) x 2 (i) $(x^2-4b)(x^4+4bx^2+16b^2)$,
(ii) $(x+a+1)(x-a-1)$, (iii) $(a^2+b^2)(a^2+2ab-b^2)$
3 (a) 20, (b) 110 4 (0 0) (−5, −3), (−3, 3)

Bom. 1928

1 (a) $\frac{2}{3}$. 2 (a) (i) $(x^2+4xy+8y^2)(x^2-4xy+8y^2)$;
(ii) $3(a+2b-c)(a+b)(b-c)$, (b) $x=\frac{1}{8}$ $z=\frac{1}{5}$ 3 (a) $-4x^2$
(b) $(5x-4)(3x-4)$ $(5x-4)(2x-5)$, (c) 2 4 (b) $x^2+2-\frac{1}{x^2}$
5. 90, 80 60 6. (a) -2 7. (b) 48 24 12, 6, 3 8. (b) 460.

Bom. 1929

1. (a) 12 2 (a) x^2-3x+4 3 (a) $10\frac{2}{3}$ 4 (a) $y=\frac{1}{2}$ $z=\frac{1}{3}$,
(b) $-4y$ 5. (a) $-\frac{1}{2}$. (b) $b\{(a^2-3b^2+5ab)(a^2-3b^2-5ab)\}$.
6 (a) $2-4\frac{1}{2}$ 7 (b) 36 9 8 (b) 25.

Bom. 1930

1. (a) $x-3$ 2 (a) $(x-\frac{3}{2})(x-\frac{5}{2})$, (b) $32\frac{5}{32}$ lbs
3 (a) $x=2$ $y=1$ (b) $x=3$ 4 (a) $\left(1-\frac{x}{3}+y^2\right)\times$
$\left(1+\frac{x}{3}+\frac{xy^2}{3}+\frac{x^2}{9}-y^2+y^4\right)$ 5 (a) $x-\frac{5}{2}-\frac{1}{x}$
6 Father 61 mother 48 son 29 7. (a) 1, 3·4 8 (a) 1

Bom. 1931

1 (a) $(x+1)(3x-5)(3x^2-2x+5)$; (b) $1\frac{1}{3}$.
2 (a) $(x^2+2xy-6y^2)(x^2-2xy-6y^2)$,
(b) $\frac{x^3+y^3+z^3-3xyz}{ax+by+cz}$; $\frac{x^2+y^2+z^2-yz-zx-xy}{a+b+c}$.
3 (a) 1. 4 (a) $\frac{a+5}{a^3+9a^2+26a+24}$ (b) 18 sq ft.
5 (a) $x^2-\frac{1}{x^2}-5$ (b) 7 6 (a) 34
7 (1) $x=1$ $y=2$ 8 Father=64; mother=58; son=38

Bom. 1932

1 (a) $\left(9x^2+5+\frac{4}{x^2}\right)\left(9x^2-5+\frac{4}{x^2}\right)$. 2 (a) $(2x-3y)(4x+3y)$
$\times(x+3y)$, (b) $\frac{1}{3}$. 3 (a) 2 or $-3\frac{1}{2}$. 4 (a) $x=10$, $y=1\frac{4}{11}$.
5 (a) 7th second (b) $1-26x$. 6 (a) 20 7. $\frac{1}{2}(x+y)$
8 No of men=125, no of days=30

Bom. 1933

1. (a) $\left(\frac{3}{x}+2x+3\right)\left(\frac{3}{x}+2x-3\right)$. 2. (a) $(x-\frac{1}{2})(x-\frac{3}{2})$ 3 $x=3$

4 (a) $x=\frac{1}{3}, y=\frac{1}{5}$ 5 (a) 1, (b) 1, exp $=-1$ 6 (b) 15 or -4.
7 Rs 360 8 (a) $(3x-4y)(9x^2+12xy+16y^2+3x+4y)$

Cal. 1925. Compulsory.

1 (1) $(x-1)(x-2)$, $(a-b)(a^2+ab+b^2)$, (2) x 2 (1) $2x+1$, (2) $(x-1)(x+2)(x-3)$ 3 (1) $x=-\frac{1}{7}$, (2) $x=\frac{18}{19}, y=\frac{7}{19}$, (3) 42

Additional 1 (1) $x=-\frac{3}{5}, \frac{15}{2}$, (2) 1, (3) $2^{-\frac{1}{9}}$
2 (1) $x^2+x-\frac{1}{4}$, (2) 27

Cal. 1926. Compulsory.

1 (1) x^8+x^4+1, (2) p^3-3p, (3) (i) $(x-2)(x-10)$, (ii) $(x+a)(x-a)(x^2+a^2)$ 2 (1) $x+1$, (3) $(x+2)(3x-1)(3x+1)$ 3 (1) $x=\frac{3}{2}$, (2) $x=2, y=3$, (3) 34

Additional 1 (1) $x=\frac{1}{3}\{a+b+c\pm\sqrt{(a^2+b^2+c^2-bc-ca-ab)}\}$, (2) 3, 27 2 (1) Sq root$=x^2-ax+2a^2$, (2) 1

Cal. 1927. Compulsory.

1. (1) x^2-x+1 (3) (i) $(x-10)(x-2)$, (ii) $(x-2)(x^2+2x+4)$
2 (1) $x-1$ 3 (1) $x=a+b+c$, (2) $x=1\frac{4}{5}, y=2\frac{1}{4}$, (3) 17 ft length, 13 ft width

Additional 1 $x=5$ 3 (2) $x=10$ 4 Parabola

Cal. 1928. Compulsory.

1. (1) (i) $(x+4)(x-7)$, (ii) $(3+x)(3-x)(9+x^2)$, (3) $(b-c)(a-c)(a-b)$ 2. (1) $x+1$ (2) 6
3 (1) $x=20$, (2) $x=1, y=2$, (3) $\frac{15}{16}$

Additional 1. (1) $x=2$, or, -4 2 (1) $x^2+2x^{-1}+x^{-2}$

Cal. 1929. Compulsory.

1 (1) $(x-3)(x^2+3x+9)$, $(a-3)(a-2)$, (2) $a^{12}+2a^6-2a^4-2a^2-1$, (3) $\dfrac{3}{(x-1)(x-2)}$ 2 (1) $x-3$, (2) 2, (3) $3(a-b)(b-c)(c-a)$

3 (1) 1, (2) $x=1, y=2$, (3) 35, 45

Additional. 2 (1) $\frac{x^2}{2}-2x+\frac{a}{3}$, (2) $=\frac{1}{2}$, (3) 7 3 (1) 38, (4) $\frac{1}{11}$.

Cal. 1930. Compulsory.

1. (1) $(2-3a)(3+4a)$, $(x-1)^2(x+2)$, (2) -9,
(3) $\left(a^2+\frac{b^2}{3}\right)\left(a^2-ab+\frac{b^2}{3}\right)$ 2 (2) $\frac{7x+5}{(x^2-1)(x+2)}$

3 (1) $-1\frac{1}{2}$, (2) $x=b+\frac{ab}{6}, y=b-\frac{ab}{6}$, (3) $10x+y$; $10y+x$, (infinite number of different solutions). (4) 25 years.

Additional 2. Art 2, Chap XVI 2 (1) 1 (double root), (2) $-8, 1$, (2) $26\frac{2}{13}$ minutes past 4 P. M. 3 (2) 10 months; (3) 6, 18, 54, (4) $\frac{a(a^n-1)}{a-1}-\frac{x(x^n-1)}{x-1}$. 4 41, or, $-2\cdot41$

Cal. 1931. Compulsory.

1 (i) $3x^2-x-2$, (ii) $(3x-4)(x-2)(2x+1)$, (iii) (1) $(2x+1)(2x-3)$, (2) $(a-2b)(a^2+2ab+4b^2)$, (iv) 7
2 (i) $ab+bc+ca$ 3 (i) $-1\frac{3}{5}$, (ii) $x=5, y=1$, (iii) $\frac{4}{7}$ 4 (2, 0)

Additional 1 (i) 1, or (i) ±2, (ii) 12, $\frac{3}{4}$, (iii) $\pm2, \pm3$
2 (ii) $\frac{7}{9}$, (iii) nth group$=\frac{1}{2}(3^n-1)$, sum$=\frac{1}{4}(3^{n+1}-2n-3)$
3 (i) 10 sq units nearly, (ii) (0, 0), (−1, 1)

Cal. 1932. Compulsory.

1 (i) x^3+1, (ii) $x=-\frac{1}{2}$, $y=\frac{1}{7}$, (iii) $(a+b+c)(ab+bc+ca)$, (iv) 24 2 One right angle

Additional 1. (i) $7, -4\frac{9}{17}$, (ii) 1; (iii) $x^2+3x+1+\frac{1}{x}$, (iv) Wrong.

2 (i) $\frac{n}{2}(a+b)$, (iii) $\frac{a(r^n-1)}{r-1}$ or $\frac{a(1-r^n)}{1-r}$ according as $r>$ or <1, (iv) 3, 6, 12 3 (0, 0), (1, 1)

Cal. 1933. Compulsory.

1 (i) $\frac{64ax^3}{16x^4-a^4}$, (iii) $a^2+b^2+c^2-ab+ac+bc$, (iv) 7.

2 (i) x^2-2x-1, (ii) $(x^2-1)(x+2)$, (iii) $(m^2+mn+n^2)(m^2-mn+n^2)$, (iv) $(a+b)(b+c)(c+a)$

Additional. 1 (i) 3 or $\frac{1}{3}$, (ii) $x^2-90x+2000=0$,
(iii) $x^{\frac{3}{4}}-x^{\frac{1}{2}}+2x^{\frac{1}{4}}-1+2x^{-\frac{1}{4}}-x^{-\frac{1}{2}}+x^{-\frac{3}{4}}$, (iv) $x^2-2xy+7y^2$.
2 (i) See Art 280, p 600, (ii) $\frac{2}{3}$, (iii) See Art 271, p 579, (iv) $\frac{n(n+1)(n+2)}{3}$. 3 (1, 3), (2, 6).

Dac. 1927. Compulsory.

1. (*a*) x^4-y^4, (*b*) $x^2+y^2+1-xy+x+y$, (*c*) $x+3$, (*d*) (i) $(x+2)(x+3)$, (ii) $(x^2+2x+2)(x^2-2x+2)$.
2 (*b*) 5. 3 (*a*) 6, (*b*) 240, (*c*) -2

Additional 1 (*a*) $(b-c)(x-b)(x-c)$, (*b*) $-13, 6\frac{3}{4}$; (*d*) x^2+2x-3, x^2-3x+2 2 (*b*) 3, (*d*) $1, \frac{1}{2}, \frac{1}{4}, \frac{1}{8}$ 3. $1, -2$.

Dac. 1928. Compulsory.

1. (*a*) $x^2-x+3+c$, *Rem.* $9-3c, c=3$; (*b*) 2, (*c*) (i) $(x+3)(x-5)$; (ii) $(a-b)(a+b-2)$ 2 (i) $\frac{3}{2}$, (ii) $x=5, y=3$, (iii) $\frac{5}{9}$

3 (*a*) 1, (*b*) $\frac{1}{a}+\frac{1}{b}+\frac{1}{c}+2=abc$

Additional 1 (*a*) $x=\frac{2+\sqrt{508}}{12}$, (*b*) 1, (*c*) $x-3-\frac{2}{x}$, (*d*) $\sqrt{\frac{2}{3}}$.

2 (*b*) 7, 12, 17 52, (*d*) 1st term 3, ratio 2 3 (*a*) (3,4), (*b*) 12 *as* per seer

Dac. 1929. Compulsory.

1 (*c*) $(x-1)(x-2)(x-3)$, (*d*) (i) $(x+7)(x-3)$, (ii) $(x-3)(x^2+3x+9)$.

2 (i) 6, (ii) $x=2, y=3$, (iii) 5 3 (*a*) 2, (*b*) Rs 400

Additional 1 (*a*) $(x-1)^2(x+2)$, (*b*) -11 37, (*c*) $\frac{4}{5}$ 2 (*a*) $\frac{1}{a^n}$; (*b*) 1, (*c*) $3(2^n-1)$, (*d*) 3, 12, 28 3 $1, \frac{3}{2}$.

Dac. 1930. Compulsory.

1 (*a*) (i) $x^4+x^3y-yx^3-y^4-\frac{y^5}{x}+\frac{y^7}{x^3}+\frac{y^8}{x^4}$; (ii) $(x-1)(x+1)(x^2+x-1)$, (*b*) (ii) 0 2 (*a*) (i) $(x^2+2x+3)(x^2-2x+3)$; (ii) $(b-c)(c-a)(a-b)$. 3 (*a*) (i) 6, (ii) $x=\frac{1}{4}, y=-4$; (*b*) 10 miles per hour

Additional 1 (*a*) (i) 8, ($\frac{1}{2}$ does not satisfy the equation, hence the reqd root is 8), (ii) 6 17, or, 73, approximately, (most probably the eqn is $10x^2-69x-45=0$, in which case the roots are $7\frac{1}{2}$, or, $-\frac{3}{5}$), (*b*) $x=3$, (*c*) (i) $(3x-14)(7x+6)$, (ii) $(x-3)(x-1)(x+4)$ 2 (*a*) 95, (*b*) $\frac{27}{8}, \frac{9}{4}, \frac{3}{2}, 1, \frac{2}{3}, \frac{4}{9}, \frac{8}{27}, \frac{16}{81}, \frac{32}{243}$ 3 (*a*) $x=8$, or, -2, (*b*) Rs 7

Dac. 1931. Compulsory.

1 (a) $\frac{2}{3}x^2+\frac{1}{2}x-\frac{1}{3}$; (c) $7y^2$ 2 (a) $(3x+1)(2x-3)$, (b) $(x^2-4x+8)(x^2+4x+8)$ 3 (a) (i) $2\frac{1}{3}$, (ii) $\left.\begin{matrix}x=0\\y=0\end{matrix}\right\}$ $\left.\begin{matrix}x=2\\y=\frac{2}{3}\end{matrix}\right\}$ (b) 42.

Additional 1 (a) $a+\frac{x^2}{2a}-\frac{1}{8}\frac{x^4}{a^3}+\frac{1}{16}\frac{x^6}{a^5}$,
(b) Reciprocal of the sq root of x^5, (c) 10^{-3},
(d) $-2x^3+x+1+x^{-1}-2x^{-2}$, (e) $x=\frac{1}{2}$ 2. (a) 6.
3 (i) 1, 3, $\frac{1}{2}(-1\pm\sqrt{-3})$, $\frac{3}{2}(-1\pm\sqrt{-3})$, (ii) 3, or, -4

Dac. 1932. Compulsory.

1 (a) $1+x^4+x^8$, (b) x^2+x-2, 2 (a) (i) $(a+1)(b+1)\times(a-1)(b-1)$, (ii) $(x+y)(y+z)(z+x)$ (b) $x^2-y^2=2$
3 (a) $\frac{ab}{a+b}$, (c) $\frac{5}{9}$

Additional 1 (a) See Art. 190, (i) p 409 (b) $x^{2^n}-a^{2^n}$,
(c) $\frac{x^{-\frac{2}{5}}}{3}-2x^{-\frac{1}{5}}+\frac{a^{\frac{1}{3}}}{2}$. 2 (a) 3. (b) See Art 275
(c) See Art 280, (d) $\frac{6}{10^2}+\frac{6}{10^3}+\frac{6}{10^4}+\dots$, $\frac{1}{15}$
3 (a) (i) $7\frac{1}{2}$ or $\frac{5}{6}$, (ii) $\pm\sqrt{\frac{2}{3}}$, $\pm\sqrt{\frac{3}{2}}$
(b) Min value$=4$, when $x=-1$.

Dac. 1933. Compulsory.

1 (a) $a^2+b^2+c^2+ab+bc-ac$, (b) $(x-2)(2x^2-x-2)(x^2+2x-12)$;
(c) (i) $(x^2+4y^2)(x+2y)(x-2y)$, (ii) $\{a(b-c)x-c(a-b)\}(x-1)$
2 (a) 0, (c) 3 on the x-axis and 4 on the y-axis.
3 (a) (i) $\frac{1}{36}\{-185\pm\sqrt{-119}\}$ (ii) $x=1$, $y=\frac{2}{3}$, $z=\frac{1}{2}$,
(b) rate of the boat$=8$ miles per hour, rate of the current 3 miles per hour.

Additional 1. (a) 43 or -42, (b) $\frac{x}{y}-\frac{y}{x}-\frac{1}{2}$, (d) ·82 nearly.
2 (b) $\frac{n(n+1)(n+2)}{3}$, (d) $\frac{1-x}{(1-x)^2}-\frac{nx^n}{1-x}$ 3. (a) $(0, 0)$, $(\frac{4}{5}, \frac{4}{5})$,
(b) at 4 for 3 pice, 120 at the 1st rate and 40 at the 2nd rate.

Mad. 1927

1. (i) $(x^2+3x+9)(x^2-3x+9)(x^4-9x^2+81)$,
(ii) $(a+b+c)(b-c)(c-a)(a-b)$ 2 (ii) 23,
3 (i) $x=\frac{13}{10}$, $y=\frac{11}{40}$, (ii) 80, or, -90, (iii) $57\frac{1}{7}$ p c

Mad. 1928

1 (i) $(9x-5)(2x+7)$, (ii) $(a-b)(b-c)(c-a)(ab+bc+ca)$.
2 (ii) $a=-30$ 3. (i) $a=-3$, (ii) $x=2$, or, $\frac{5}{2}$, (iii) Rs 800 4 4.

Mad. 1929

1 (i) $(3x^2+y^2+xy)(3x^2+y^2-xy)(9x^4+y^4-5x^2y^2)$, (iii) $(b-c)(a-c)(a-b)(a^2+b^2+c^2+ab+ac+bc)$ 2 (ii) $x^{\frac{4}{3}}+x^{-\frac{4}{3}}+x^{\frac{2}{3}}+x^{-\frac{2}{3}}$
3 (a) (i) $-\frac{5}{2}$, (ii) $x=\frac{1}{10}$, $y=-\frac{1}{10}$, (b) $7\frac{1}{2}$ 4 -7, -4 3

Mad. 1930

1 (i) $(3x+4y+1)(2x-3y-2)$, (ii) $(a-b)(b-c)(c-a)(ab+bc+ca)$.
2. (i) $\dfrac{2x+5}{(x-1)^3(x-3)}$ 3. (i) (a) 6, (b) $x=\frac{1}{3}$ or, $-\frac{1}{5}$, $y=\frac{1}{4}$ or, $-\frac{1}{7}$, $z=\frac{1}{6}$ or, $\frac{1}{28}$ (ii) 1 mile 4 4 1 or -1 1, approx.

Mad. 1931

1 (i) 110, (ii) $l=-4$, $m=10$ 2 (i) $(x^2+4xy+y^2)(x^2-4yx+y^2)$;
(ii) $\dfrac{a^2+b^2+c^2}{a+b+c}$. 3 (i) $x=-1$, $y=\frac{1}{2}$ (ii) 3 lbs from the 1st and 6 lbs from the 2nd 3 2 189 or, -1 522

Patna 1928

1 (a) $2ax-(3b-4c)y$, (c) x^2-3x+2, (d) $(2x+3)(2x-3)\times(4x^2-6x+9)(4x^2-6x-9)(3x+2)$ 2 (a) 1, (c) $2a^2+3a+\dfrac{3}{a}$;
(d) $x=35$, or, -12. 3. (a) (1, 1), (b) 72

Patna 1929

1. (a) $1-y^{\frac{1}{2}}+x^{\frac{1}{2}}y^{-\frac{1}{2}}+y^{\frac{1}{2}}+x^{\frac{1}{2}}y^{-1}+x^{-\frac{1}{2}}y^{\frac{1}{2}}-yx^{-\frac{1}{2}}$,
(b) $(x+a+b)(x-a-b)(x+a-b)(x-a+b)$, (c) $\dfrac{x^2-2x+1}{x^2-3x+1}$,

(*d*) $(x+2)(x-1)(x+3)(x^2-3x-1)$ 2 (*a*) 1, (*c*) -17, [illegible];
(*d*) $3x+x^{\frac{1}{3}}-2x^{-\frac{1}{3}}$ 3 (*b*) Man in 18 days, boy in 36 days

Patna 1930

1 (*a*) $(x+1)(x+2)(x-2)(x+5)$, (*c*) H.C.F. $=x(2x^2+x+1)$,
(*d*) L.C.M. $=6x(x+1)(x-3)(x-4)$ 2 (*a*) $x=\frac{2}{3}$, or $-\frac{3}{5}$,
(*b*) $c=1$, (*c*) Increase from 1 to 7. 3. 80 years

Supplementary Paper

1 (*a*) $p=-2$, (*b*) $(b-c)(c-a)(a-b)$, (*c*) 0 2 (*a*) H.C.F.
$=x^2-x+1$, (*b*) L.C.M. $=(x-1)(x+2)(x-3)(x^2+1)$,
(*c*) $x=7$, $y=2$, (*d*) 54 3. (*a*) $x=10\frac{1}{2}$, or, -10,
(*b*) Sq. root $=3a^{\frac{1}{2}}-2-2a^{-\frac{1}{2}}$

Patna 1931

1 (*a*) 0, (*b*) $\dfrac{1-x-2x^2}{2+x+x^2}$ 2 (*a*) -2, or, $\frac{1}{7}$, (*b*) $x=-\frac{10}{3}$.
3 (*a*) $x^{\frac{5}{6}}-2x^{\frac{1}{2}}+x^{-\frac{1}{6}}$, (*b*) 2 miles per hour, 4 miles per hour

Supplementary Paper

1 (*c*) $2x-y$, (*d*) $\dfrac{3}{x^2-4x+3}$ 2 (*a*) $-\frac{1}{3}$, or, $\frac{7}{5}$,
(*b*) $x=8$, (*d*) $x=3, y=11$. 3. (*b*) Man 20 days, boy, 60 days.

Patna 1932

1 (*a*) $x^8-2x^6+x^4+4x^3-1$, (*b*) $2x+3$, (*c*) 1,
(*d*) $(x-2a)^2(x+2a-y)(x-2a+y)$ 2. (*a*) $a^2+b^2+c^2+2ab$
$+2ac+2bc$. (*c*) $x=1, y=1$, (*d*) $a=24$ 3 (*a*) 4 or 7,
(*b*) Father's age=40 years, son's age=10 years.

Patna 1933

1. (*a*) (i) $\{(a-b)x+(a+b)y\}\{(a+b)x-(a-b)y\}$;
(ii) $(y-3)(x-y+2)$, (*b*) $x-2$, (*c*) 0 2 (*a*) $\frac{1}{15}(-1\pm\sqrt{166})$;
(*b*) $a=12$ 3 (*a*) (3, 12), (*b*) rate of rowing=4 miles
per hour and rate of the current=1 mile per hour.

Pun. 1925

1 (i) $(3x-\sqrt{2x}-\sqrt{2y^2})(3x+\sqrt{2x}+\sqrt{2y^2})(3x+\sqrt{2x}-\sqrt{2y^2})(3x-\sqrt{2x}+\sqrt{2y^2})$, (ii) $(x+1)(x-1)(x^2+x+1)(x^2-x+1)$ 2 (i) $x=106$, (ii) $x=3, y=\frac{1}{2}$ 3 (i) $a=6$, (ii) a^3-3a 4 $x=6, y=-4$, the intercepts are 8 and -16 5 (ii) $m^2-n^2=4$, (iii) $10\frac{1}{2}$ miles

Pun. 1926

1 (i) $(x+2)(x-2)(x^2+2x+4)(x^2-2x+4)$, (ii) $(x^2-3x+1)(x^2+3x+1)$ 2 (i) H C F $=1$, (ii) $\sqrt{2}(x^2+xy+y^2)$ 3 (i) $x=\frac{12}{41}$,

(ii) $x=\frac{pr}{p^2+q^2}, y=\frac{qr}{p^2+q^2}$ 4. $x=3\frac{1}{2}, y=2\frac{1}{2}$

Pun. 1927

1. (i) $(2x+1)(4x^2-3x+1)$, $(x^2+2x+3)(x^2-2x+3)$, (ii) $2x^2+3x+2$

2 (i) $x-2-\frac{1}{x}$, (ii) 1154 3 (i) $x=7$, (ii) $(-1, -1)$

4 (ii) $(a^2+b^2-c^2)xy+ab(x^2+y^2)=0$.

Pun. 1928

1. (ii) $(x^2+2x+3)(x^2-2x+3)(x^4-2x^2+2)$, (iii) $(x-1)(x-3)(x+3)(x-2)$ 2 (ii) x^2-5x+4, (iii) 2 3 (i) $-2\frac{1}{1}$.
4 (ii) $a^2y^2=b(x^2-a^2)$

Pun. 1929

1 (iii) $x=15, y=3$ 2 (i) $(x-5)(x+3)(x+2)$, (ii) $(x-2)(2x-1)$,

(iii) 4 4 (ii) $x=2$, $y=3$ 5 (ii) $n=x^{m^{\frac{1}{x}}}$.

Pun. 1930

1 (a) 5430^3, (b) 16, (c) $6x^6+4x^5+42x^4+5x^3-12x^2-35x+15$.

2. (a) $x=\frac{c_1b_2-c_2b_1}{a_1b_2-a_2b_1}$, $y=\frac{c_1a_2-c_2a_1}{b_2a_1-b_1a_2}$, (b) $x=3, y=4$.

3 (a) 1, (b) $\frac{1}{abc}$, (c) $\frac{2}{7}$ 4 (b) Rs 57, (c) v^2-u^2

Pun. 1931

1 (a) Quot $=2x+1$, rem $=5-mx$, $x=\frac{5}{m}$, (b) x^2+2x+3

2 (a) $(p+q)(p+2r)(p+3s)\equiv p^3+p^2(q+2r+3s)+p(2qr+6rs+3sq)+6qrs$ 3 (a) $x=15, y=10, z=17$, (b) $x=\frac{1}{2}$

4 (a) $\dfrac{x+a}{x^2-bx+b^2}$; (b) $x^2+y^2+z^2+2xyx-1=0$

5 (a) (1) 36 ft (2) 25 ft, 11 ft; (b) $A=2, B=-4, C=3$.

Pun. 1932

1. (a) $x=p+q$, (b) $x=45$; $y=46$ 2 (a) $2(5x^4+10x^2+1)$, (b) $2x^2+2x+1$, 221 3 (a) $(x+5)(2x-3)(x+1)$, (b) $\dfrac{a}{a-b}$

4 (a) $x=28, y=3$ 5 (a) $m^2-n^2=4ab$, (b) $A=3$, $B=-2$, $C=1$ (c) 115 625 gallons

Pun, 1933

1 (a) $(x+3)(x-3)(x^2+3x+9)(x^2-3x+9)$, (b) c^3+3c 2 (a) $\frac{1}{3}$; (b) $\sqrt{7}-\sqrt{3}$ 3 (a) 16, (b) $x(2x-3)$. 4 (b) $x^2-y^2=4$.

5 (a) $x=3, y=12$